

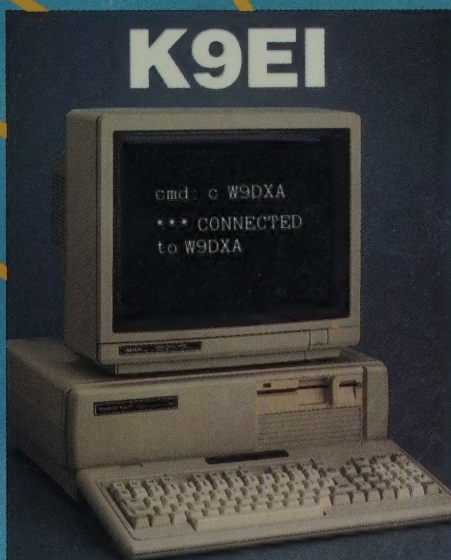
# Digital Communications with Amateur Radio

The Complete  
Packet Radio  
Book

Radio Shack

\$16.95

By: Jim Grubbs  
K9EI



Developed and Published by  
Master Publishing, Inc.





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## The Complete Packet Radio Book

By: Jim Grubbs  
K9EI

**Radio Shack®**

A DIVISION OF TANDY CORPORATION  
FT. WORTH, TEXAS 76102

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*This book was developed and published by:*  
Master Publishing, Inc.  
Richardson, Texas

*Design and artwork by:*  
Plunk Design  
Dallas, Texas

*Editing by:*  
Charles Battle  
Plano, Texas

*Printing by:*  
Arby Graphic Service, Inc.  
Chicago, Illinois

*Acknowledgements:*

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# Foreword

## (Store and) Forward

It is without exaggeration that we compare the arrival of packet radio to the significance of other communications innovations such as single-sideband, FM-repeater, satellite relay and cellular mobile telephone. Each of these innovations did not completely displace earlier developments, but each contributed vast improvements in communications efficiency. So it is with "packet."

Packet is a marriage of radio and computer communications. It is like networking without wires; like having a modem connecting two computer terminals by radio rather than by telephone lines. Packet radio can be used to exchange anything that can be digitized, including text, voice, pictures and music. Packet radio uses high data-transfer rates, enabling many users to efficiently share one operating channel.

Can you imagine the excitement of the early "wireless" pioneers as they made their first contacts, extended the working distance between their stations and seeing practical uses evolve from their technical novelty? These pioneers made history. Packet pioneers are making history today, extending wireless webs ever farther, making them more sophisticated, and, at the same time, more convenient for the rapid exchange of information.

From the beginning, hams have provided to the public, free of charge, a non-commercial message communications service. It is for this service that Amateur Radio is most widely recognized. Hams prepare themselves for this service with training drills and routine exchange of messages. While most message handling is done using code, voice and radio-teletype, packet is emerging as an incredible time saver in emergency and disaster communications.

Using the power of the computer coupled with the freedom afforded by radio data links, packet pioneers are developing a nationwide automatic message-forwarding network. During an emergency or natural disaster, packet provides not only lightning-fast written messages, but also can provide maps, drawings, pictures and data that can be relayed for immediate or delayed study and subsequent action by appropriate authorities.

The work of individuals and of small groups has resulted in many communications advancements, especially in the field of packet, but there is much untilled ground waiting for the fertile plow of human imagination. It is hoped that this book will serve as an inspiration and an invitation to explore, to have fun and to contribute in your own special way to the advancement of communications science. Amateur Radio offers an unusual opportunity for personal growth, enjoyment and fulfillment. Amateur packet radio extends these opportunities by enabling you to put to good use your fascination with digital communication. Join us, and pass it on!

David A. Wolf W05H (ex-WA6GVD)

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# Preface

You are on the verge of entering a world that combines the best of hobby computing and Amateur Radio communications. Whether you are a confirmed computer hacker or a died-in-the-wool radio communicator, this book is for you.

Amateur Radio operators have enjoyed using digital communications techniques for years. They started with Morse code and now employ packet radio, a state-of-the-art means of providing error-free communications. With the expansion of privileges available to entry level ham operators via the new Novice class license, just about anyone can easily obtain the necessary Federal license that will allow him or her to use radio waves for computer communications.

We begin by reviewing the basics of telephone line digital communications and learn how to apply them to Amateur Radio communications. We continue with an overview of basic digital techniques and discuss interface techniques for physically mating computers with Amateur Radio equipment for a variety of digital communication modes.

The star of the show is packet radio. For hobbyists, packet techniques offer a highly reliable, low-cost way to communicate keyboard-to-keyboard with other hobbyists. Perhaps more importantly, packet radio provides a means for exchanging computer programs, as well as extensive bulletin board operation, via radio waves so you don't tie up the family telephone line.

It doesn't have to be expensive or difficult to get involved with digital radio communication. Chances are good that you already have at least half of the necessary equipment, and maybe more. So let's get started. The marriage between computer and radio is a natural one!

J.G.



# Introduction

## ABOUT THIS BOOK

Whether you are a computer hobbyist, an Amateur Radio operator, or both, the chances are excellent that you enjoy communicating with your fellow hobbyists.

This book is about the marriage of computer technology with Amateur Radio communications. There are several forms of digital communication that we will learn about. The star of the show is *packet radio*, and we will be devoting most of our attention to its operation. You may have already heard about packet radio and wondered what it is and how it works. You'll find the answers in the pages ahead, but first, let's find out how packet radio can add to the enjoyment of your hobby.

## COMPUTERISTS

Computers are everywhere these days. They've been integrated into many of the items we use in our everyday lives. They do many things, but one of the things they do best is pass information from one point to another using a simple communications path. This simple communications path can be external or internal to the computer.

Inside the computer data is flowing everywhere. The microprocessor chip communicates with the other circuits in your PC. It sends and receives data from a disk drive. It sends and receives data to and from memory. It receives data from the inputs, and sends data to the output.

Externally, computer data is sent and received over telephone lines. An example is the automatic teller machine (ATM) at the bank. The ATMs are dedicated computer terminals that communicate over telephone lines with the bank's computer across town or across the street.

## Communicating via Modem

As a computer enthusiast, there's a good chance you've experienced the fun of connecting the PC in your home with other computer systems via telephone lines. One application is to a so called bulletin board. You or any person who gains access to the bulletin board may post information in the bulletin board for others to see. The popularity of bulletin board systems across the country and around the world has grown dramatically over the past several years. Another application is computer

games. Some hobbyists enjoy playing games with other enthusiasts without any participants ever leaving the comfort of their own homes.

For many, the marriage of computer and telephone line becomes the principal way to communicate. Every day, thousands of pieces of mail are delivered electronically to recipients around the world. While commercial networks provide exchange of business correspondence, hobbyists have devised their own special networks using commonly available telephone lines that can relay messages to almost any point on earth.

Coupling the computer to the telephone line can also be an inexpensive way to expand your computer software library. Many bulletin boards and national information services like CompuServe® have on-line libraries of programs for just about every computer ever produced. For the cost of a telephone call and maybe a special connection charge, you can access the library and the program is yours.

Some countries have expanded the electronic mail much further. For example, in France, many homes have a very inexpensive computer terminal that delivers news and information to the home on demand. The same system provides an electronic telephone directory that virtually replaces the familiar printed version. Telephone companies in the United States are just beginning to look at offering similar services.

## Data in the Air

What may come as a surprise to you is that data is also flowing right by your head as you read these words. Electromagnetic waves of all kinds are carrying computer information to points around the world without using wires to do so! Computer signals are transmitted on the subcarrier of FM broadcast stations, on microwave line-of-sight links across country, or by satellite hops across nations. Commercial and Amateur Radio satellites in orbit high overhead carry billions of bytes of computer communications linked only by radio waves from a satellite antenna to a ground station.

The same radio link is being used everyday by Amateur Radio hobbyists that own home computers. Tens of thousands of Amateur Radio hobbyists around the world are using specialized techniques that tie their home computer system to others via radio link rather than telephone line. How can you as a computer enthusiast enjoy these privileges? An Amateur Radio license is required, but recent changes in Federal regulations make it relatively simple to obtain the required license. With relatively inexpensive equipment and readily available instructional materials, you can be on your way.

## The Requirements for Radio Linkup

In early 1987, at the urging of the Amateur Radio community, the FCC took action to redefine the requirements and privileges available for beginning radio enthusiasts. Today, a 30-question test covering very basic electronic and radio theory and a modest Morse code test will earn you an astonishing variety of Amateur Radio privileges. The class license is the Novice class.



## Why is a License Required?

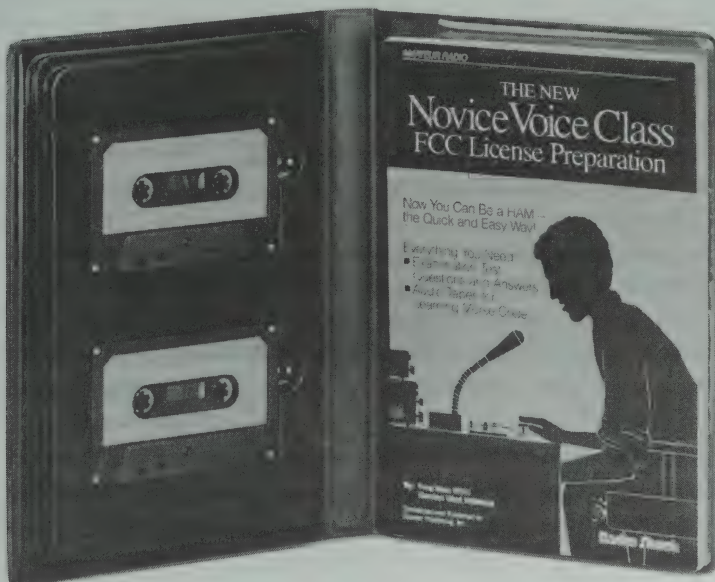
It is important to emphasize that under today's rules and regulations, if you, as a computer enthusiast, want to use radio links to communicate as you do with telephone lines, you can make such transmissions only after you are a properly licensed Radio Amateur. There are petitions before the Federal Communications Commission (FCC) to create a digital type of citizens band service. An initial proposal was rejected by the Commission in 1986. The biggest problem is trying to locate an area in the frequency spectrum for such a service. Radio frequencies are a valuable, limited resource. We will most likely see a consumer class service in the future, but for now, an Amateur Radio license is the key. In addition to your computer hobby, you would have the excitement of Amateur Radio communications to go with it.

## Studying for the Exam

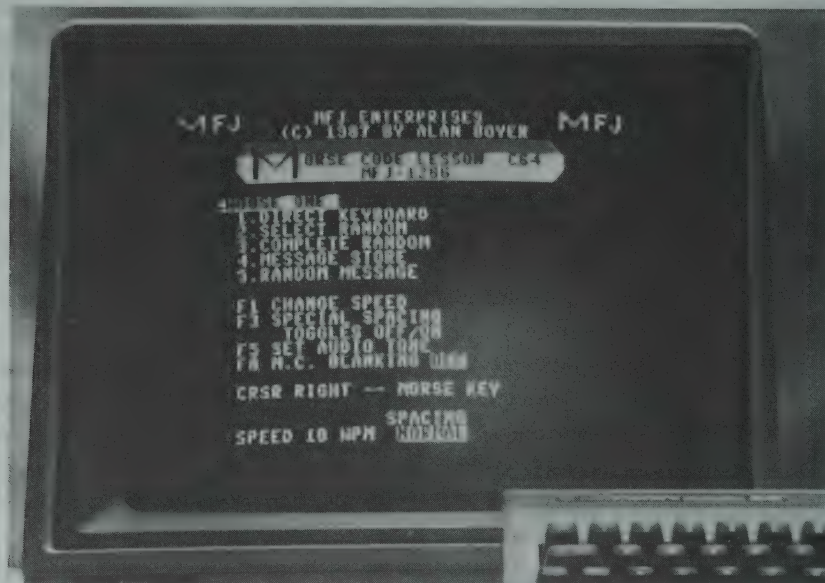
Noted amateur radio operators, Gordon West and Fred Maia, have authored a special package for Radio Shack titled *New Novice Voice Class* (RS# 62-2402) which will teach you everything you need to know to pass the entry level examination in just a few short weeks. (See *Figure 1-1*.)

Computer hobbyists can even use their computer to help them practice Morse code. *Figure 1-2* shows the screen menu for an MFJ Enterprises, Inc. computer program to aid in learning Morse code. Using such a program will help you prepare to pass your required Novice Morse code examination of five words per minute.

**Figure 1-1. The Gordon West and Fred Maia license preparation course available from Radio Shack contains everything you need to prepare for the new Novice voice class FCC license.**



**Figure 1-2.** The menu screen of a computer program that can help to learn Morse code.



*Courtesy of MFJ Enterprises, Inc.*

With your Novice class license in hand, you are authorized to operate on a variety of frequencies from shortwave, which allows world-wide communication, to microwaves, where experimentation and satellite operation are common. With Novice privileges, you not only can communicate by Morse code transmissions, but you also have limited voice privileges which make possible international contacts on the 28 MHz band and walkie-talkie operation on the 220 MHz and 1.2 GHz bands.

## Novice Digital Communications Privileges

Of course, as a computer bug, you are most interested in the new digital communications possible after you have a Novice class license. On the same frequency bands available for voice, Novice class operators can participate in digital communication networks. This includes transmission of data using the American Standard Code for Information Interchange (ASCII) as well as traditional radioteletype techniques.

Also included are more advanced forms of transmission that allow not only error-checking, but also error-correction during transmission. A specialized synchronous form of radioteletype called AMTOR is authorized, as well as packet radio. Don't worry if these terms are foreign to you. They are fully explained in the pages ahead. This book will help you build on your computer experience and understand and enjoy packet radio communications.

The excitement ahead for you is that just about anything you can do with a computer via telephone line can be done by substituting a radio link in place of the telephone connection. The possibilities are staggering!



## **RADIO HOBBYISTS**

If you are already a licensed Amateur Radio operator, or perhaps a shortwave listener already familiar with radio communications, you may be somewhat puzzled by computers and computer communications, and somewhat hesitant to jump in and get involved with packet radio. This book will help you as well. It will provide you with the basic understanding of digital communications, and the specifics of packet radio communications.

While packet radio isn't of interest to everyone, it has proven very popular with the Amateur Radio community. In just a few years, over 30,000 active stations have joined the packet radio network. This did not happen overnight; it required a great deal of early pioneering by dedicated people.

## **Early Data Communications**

Data communication has been with us since men and women first appeared on Earth. The basics for digital communication can be traced back hundreds of years, but the specific techniques we use today have their roots in technology created within the twentieth century. As the century began, scientists and wireless experimenters, or hams, began to prove that worldwide communication was possible via radio.

Actually digital communications started before voice communications. A modified version of the on-off code created by Samuel Morse for wired telegraph systems was used. Voice transmission came afterwards.

Through the years, the forms and techniques of digital communication were created. Today, a large majority of the digital communications are sent using ASCII, which has become a universal language for digital communications. ASCII also is used in most home and personal computers.

## **Canadian Digital Class License**

Packet radio, the most advanced form of digital communications via radio, was born in Canada about a decade ago. The Canadian government created a special class of Amateur Radio license especially for computer enthusiasts. It required the applicant to pass a stringent test on digital techniques and regulations, but no Morse code test was required. Only computer communications were permitted.

A group of radio and computer enthusiasts in the Vancouver area, led by Doug Lockhart, began creating a special network. They called the system "packet radio" because all of the information destined for the same location was packed together into small bundles before transmission. The techniques they developed were loosely based on special telephone-line computer networks.

## **Packet Radio in the United States**

In the early days of packet radio activity in the United States, operation was only allowed by a select group of fully licensed amateurs specially authorized by the Federal Communications Commission. After these stations successfully proved the viability and usefulness of the system, the FCC approved packet radio operation for all classes of Amateur Radio operators with a Technician or higher class license.

The first people to try packet had a difficult time. There were very few active stations. It was difficult to find someone with whom to communicate. There was no commercially manufactured equipment available. Even the details of packet radio protocol, the definitions that determine the make-up of packet transmissions, had yet to be standardized.

Much progress has occurred over the past few years. Amateur Radio operators have begun to successfully create a world-wide data network. There is still much work to be done, but that adds to the excitement because Amateur operators joining the forces now can participate in shaping the future of radio data communication.

## **PACKET RADIO FEATURES**

What can you do with an Amateur Radio packet station? The answer to that question is being expanded every day, but here are just a few examples.

### **Keyboard Communications**

If you enjoy having a “conversation” via your computer keyboard, packet radio allows you to do the same thing using a radio link in place of a telephone line. Frankly, if this were the only thing packet radio could do, there wouldn’t be much need for it. But packet radio allows you to do so much more.

### **Program Exchange**

With a packet radio station, you can exchange computer programs via the airwaves with absolutely no errors — guaranteed! No longer will you need to tie up the family phone line just to trade programs with your friends across town, or even around the world.

### **Bulletin Board Operation**

Thanks to the efforts of several Amateur Radio enthusiasts, a network of radio bulletin boards is available to packet operators. Not only can you send and receive messages to other local operators, but by using the store and forward capabilities of many BBS (bulletin boards system), you can also exchange messages with other enthusiasts around the world.

### **Satellite Communications**

Both current and proposed Amateur Radio satellites allow global packet radio communications. Packet radio was even scheduled to fly aboard the Space Shuttle before the tragedy of 1986. If future plans come true, amateur radio, especially digital communication, will be part of the permanent space station. This area is so exciting that a separate chapter, Chapter 10, is dedicated to satellite operation.

### **Additional Features**

If that isn’t enough, experiments are under way to use packet radio for the transmission of digital audio and full-motion digital video. Many specialized applications have also been developed to serve segments of the Amateur Radio community. There are packet operations that allow users to easily check propagation conditions. An



online listing by callsign of Amateur Radio stations recently became available via packet. The possibilities are limited only by the imagination of packet operators.

## EQUIPMENT REQUIREMENTS

Once you are licensed, how do you connect your computer to a radio? It's much easier than you might imagine, and it gets easier every day. Specific details are covered in upcoming chapters, but a quick overview should help you to understand what's involved.

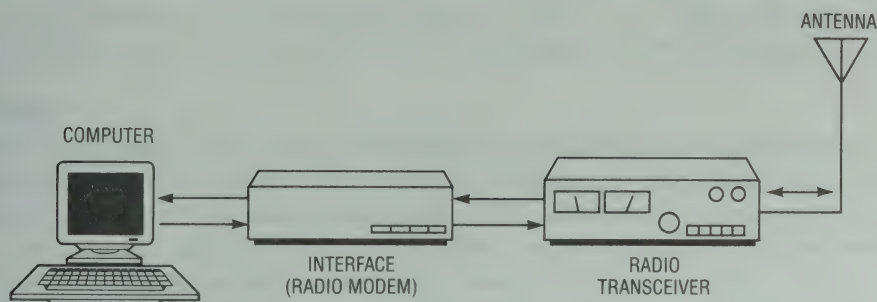
### Computer

As shown in *Figure 1-3*, there are three basic elements in a Amateur Radio data communications system. First, your home computer is the device most commonly used to create and store messages and programs for transmission and reception. Nothing special is required. The very same software you normally use for telephone communication works just fine.

### Interface

Secondly, you need an interface to connect your computer system to the radio equipment. That sounds somewhat intimidating and costly, but it needn't be. An interface is nothing more than a modem designed especially for connecting a computer and radio system. Just as with telephone modems, cost is dependent on the number of features you want or need for a particular kind of transmission. Telephone modems range in price from well below fifty dollars to a thousand dollars or more for special high-speed smart modems. The same is true for radio modems.

**Figure 1-3. The three basic elements in an Amateur Radio data communications system are a computer, an interface (radio modem), and a radio transceiver and antenna.**



While they perform a similar function, telephone and radio modems are not interchangeable. Just as different techniques are used on 300 and 1200 baud telephone modems, special transmission methods are employed in radio modems.

## **Radio Transceiver**

Nearly everyone has a telephone line, but only Radio Amateurs are likely to already own the necessary radio equipment. A common mistake is to imagine that the radio equipment itself must be expensive. Others may be concerned about the size of the equipment, or the difficulty in mounting a proper antenna. While the most versatile stations are equipped with sophisticated radio gear and large antennas, they are not a requirement, especially for enjoying digital communications!

For Novice class operators, a small radio, the size and cost of a hand-held scanner, will work nicely. In metropolitan areas, you may even be able to use the short (6-inch) flexible (“rubber ducky”) antenna attached to the radio! If not, a small antenna about one foot long will more than likely do the job. It is not only inexpensive, but can also be hidden in the attic if need be. Even with such a simple system, packet radio will allow you to send and receive messages from around the country. The secret of how to do this is in the pages ahead.

## **Let's Begin**

In order to gain an understanding of how packet and other digital radio techniques work, it is important to begin by defining the terms used in the world of digital communication.



# Digital Communications Techniques

## ANALOG AND DIGITAL

As you view the world around you, think about how you define the objects and events that you see. The tree in your front yard may be green, but is it a dark green or a lighter shade? Is it always the same shade of green or does it change color?

Perhaps you drive a 1987 model automobile. It replaced your 1983 vehicle. Even ten years from now, it will still be a 1987 model. For the most part, the model year is always a whole number. (Though some manufacturers do insist on dubbing units with numbers like 1985 1/2.)

Think carefully before answering the next question. How old are you? If you answered with a whole number, rethink your answer. Are you the same age now as you were when you first answered the question? Of course not. Though it is only a small change, you have aged by a few seconds. Your age is a constantly, although predictably, changing quantity. It's always increasing.

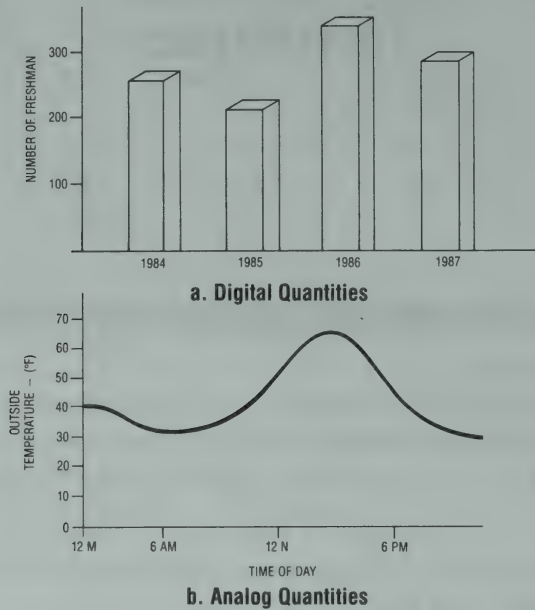
In the sports arena, it's impossible to have a football score of 4.5. The scores are always whole numbers; they are the result of specific point values assigned to certain events. Similarly, the number of freshman in a particular school for a particular year is a discrete, whole number as shown in *Figure 2-1a*. On the other hand, the outside temperature varies smoothly over a wide range as shown in *Figure 2-1b*.

## Analog

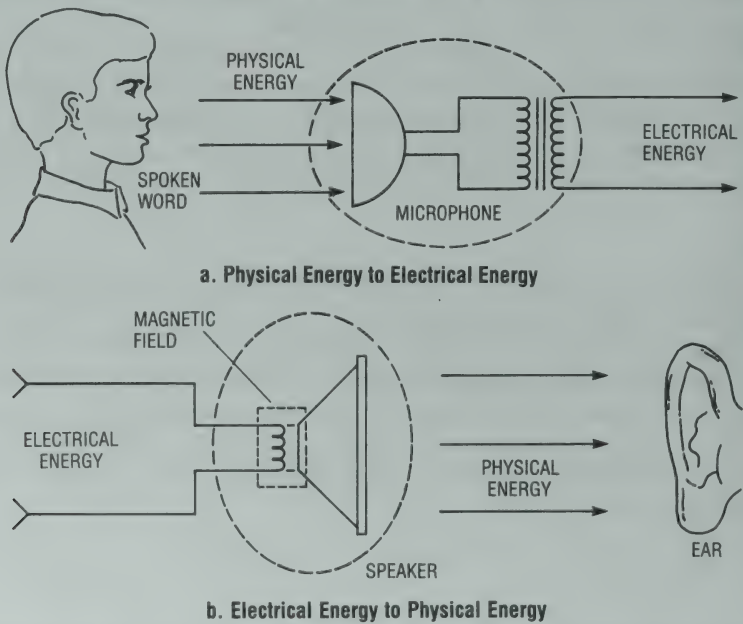
If the value, shape, color or other characteristic of something does not change in distinguishable steps, it is an *analog* quantity. Your age, the color of tree leaves, the outside temperature (*Figure 2-1b*), and most things governed by nature are analog.

As indicated in *Figure 2-2a*, a microphone transforms human speech, an analog form of communication, into an electrical current that continually varies in accordance with the strength and frequency of the physical energy. At the output end, a speaker transforms the continuously varying analog current into physical energy so the ear can hear it (*Figure 2-2b*).

**Figure 2-1.** The bar graph in *a* shows how discrete or digital values can be portrayed graphically. The plot in *b* shows temperature variation over time — a typical analog quantity.



**Figure 2-2.** In *a*, human speech is transformed from physical energy into electrical energy by a microphone. In *b* electrical energy is converted into physical energy by a speaker.





## Digital

When something changes in discrete steps or units, it can be thought of as a *digital* quantity. There is no in-between. The football score, the model year of your car, and the number of freshmen (*Figure 2-1a*) are digital values.

Digital computers know how to evaluate only two conditions. Everything is either on or off, high or low, one or zero; thus, computers communicate in digital form. Since the computer works in binary (meaning two conditions), each of its digits is a *binary digit*, or *bit*.

All modern computer communication is done in digital form. Analog computers do exist, but they do not lend themselves easily to modern techniques.

In communications, distinguishing between analog and digital quantities is very important. With analog transmission techniques, an infinite number of points or values can be transmitted and received. With digital transmissions, only discrete values can be transmitted and received.

## Converting Analog to Digital

In many cases, we can *digitize* an analog quantity; that is, convert it into a digital quantity, and still be very close to its actual value. That's important to remember. Even analog quantities like sounds and pictures can be converted to digital form. Later in this book, we'll learn some of the advantages realized when analog quantities are converted into digital form, and we'll see how the conversion is accomplished. The techniques involved are a bit advanced for us at the moment, so let's explore some additional terminology before tackling that subject.

Let's consider for the moment how we are going to transmit digital information from one place to another. Our familiarity with the telephone will help to explain two additional terms, serial and parallel, which are common in data communications.

## SERIAL

A single pair of wires connects each telephone to the central office. Without using special equipment and techniques, each pair of wires can carry only one conversation at a time. Once the conversation is completed, the same pair of wires can be used to carry another conversation, and then another.

If Bill and Susan both want to make a phone call at the same time, they can't do it with only one telephone set and one line. Susan can make her call, then when she finishes, Bill can make his call. The two calls are in series on the one line.

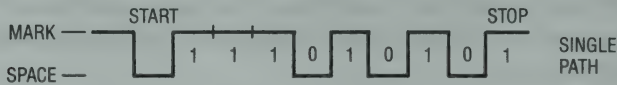
Similarly, if only a single pair of wires is available, digital information must be transmitted one bit at a time along the wires, as indicated in *Figure 2-3*. This is *serial* transmission.

## PARALLEL

If Bill and Susan have access to two telephone sets, and if each is on a separate line, they can place their calls at the same time. The two calls occur in parallel, but two lines are required.

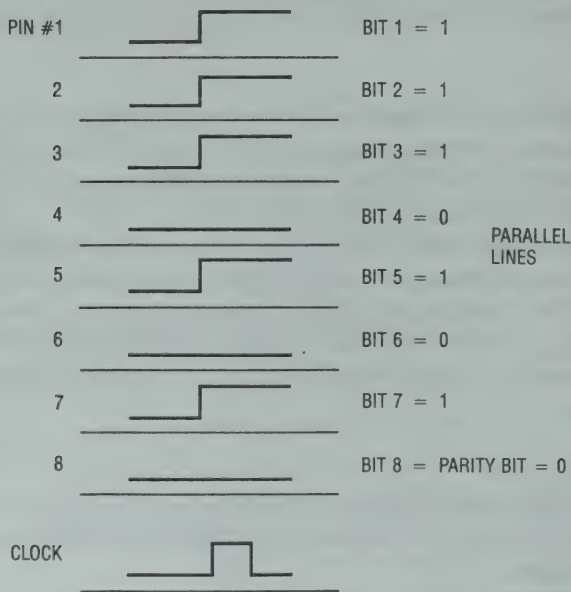
Internally, computers transfer data by moving several bits at one time. The number of bits that can be transferred at one time is called a *byte*. For personal

**Figure 2-3.** Serial transmission is the transmission of the information bits in time sequence, one after another, over a single path. Shown is an ASCII “W” being transmitted as serial data with odd parity.



computers, a byte is usually eight bits. When a number of pieces of information are all sent via a common circuit at the same time, as indicated in *Figure 2-4*, the transmission is said to be in *parallel*. The number of communications paths inside the computer must equal the number of bits to be transferred at one time. Actually, it usually takes more than eight communications paths to transfer eight bits of data in parallel because other signals are needed to coordinate the activity and these add to the number of paths required.

**Figure 2-4.** In parallel transmission, all the bits of a byte or word are transmitted at the same time, each over a separate wire. Shown is an ASCII “W” being transferred as parallel data with odd parity.





It's very efficient for computers to communicate internally over parallel paths. Even short distance external communications can be accomplished using parallel transmission. For example, a parallel connection is often used to send information to a printer that is located within a few feet of the computer. All the bits in a byte are sent at one time.

Parallel transmission becomes difficult and expensive as the distance increases. Suppose your computer is located on the second floor of your home, and the printer is in the basement. Shielded, multiple conductor cable must be used to connect them, and special amplifiers must be used on each wire to make up for the signal loss in the long wires.

A similar problem would occur if radio transmission were used instead of wires. For parallel transmission, each bit would need a separate radio channel. This, of course, is not practical.

Fortunately, there is a way to convert parallel data to serial data, so that only one transmission path is required. Let's find out what it is.

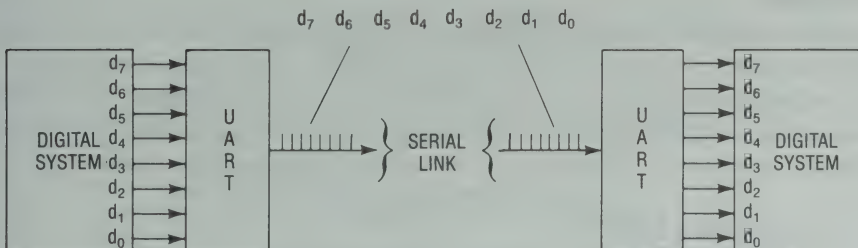
## CONVERTING FROM PARALLEL TO SERIAL

An electronic circuit, called a *universal asynchronous receiver/transmitter* (UART), converts parallel data to serial data, as shown in *Figure 2-5*. The UART receives eight bits of information in parallel from the computer and stores them temporarily in a special group of memory cells called a shift register. The UART then outputs the bits serially, one bit after another, to another part of the modem circuitry. When receiving information, the UART operates in reverse, converting the serial bits back into parallel form.

## TYPES OF TRANSMISSION

Now let's see how the digital serial data gets from one place to another.

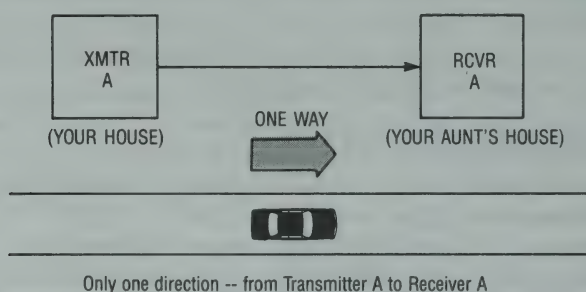
**Figure 2-5. Parallel data from your computer must be converted to serial form before it can be sent over a telephone line using a modem. A special circuit designed for this purpose is a UART.**



## Simplex

Let's take a drive around the city for a moment. Our destination is your aunt's house. She lives on a street that is one-way from your house to hers, as shown in *Figure 2-6*. You can get to her house by driving down the one-way street, but you cannot return home using the same street. In communications terms, a one-way street is analogous to a *simplex* communications path. There is only one channel, and it goes from one point to the other in a single direction.

**Figure 2-6. When using a simplex communications path, information flows in one direction only.**



## Full-Duplex

Now suppose that, rather than a one-way street, the street has two lanes with one lane in each direction, as shown in *Figure 2-7*. You can go to your aunt's house and return home on the same street. In fact, if she happened to start for your house at the same time you left for hers, you would pass along the way. There are two lanes of traffic, each flowing in the opposite direction. In communications terminology, a street with one lane in each direction is analogous to a *full-duplex* communications path. (Sometimes just the word duplex is used instead of full-duplex.)

## Half-Duplex

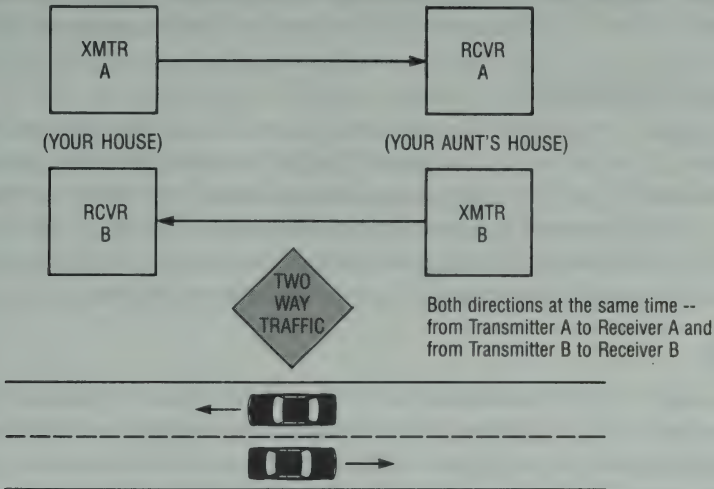
Finally, let's imagine that the same two-way street exists, but one lane is temporarily closed for repair, as shown in *Figure 2-8*. At each end of the single-lane section, there is a flagman to allow traffic from both directions to flow alternately, but not at the same time. In communications terminology, the single-lane section with flow in alternating directions is analogous to a *half-duplex* communications path.

## How the Types Are Used

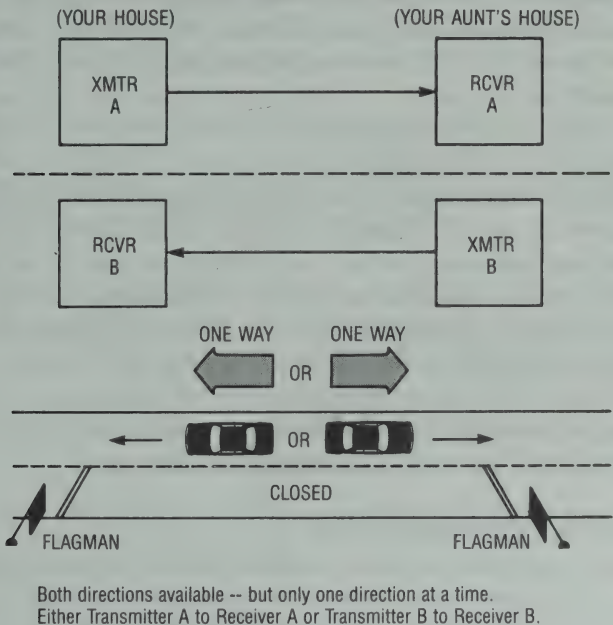
Early data communications over telephone lines were simplex or half-duplex. Because a dc current was keyed on and off as in the early days of wired telegraph circuits, the telephone circuit was capable of supporting only one lane of traffic at a time.



**Figure 2-7. When using a full-duplex communications path, information can be sent and received over the same circuit simultaneously.**



**Figure 2-8. When using a half-duplex communications path, information can be sent in only one direction at a time. The path can be reversed to allow data to flow in the opposite direction.**



Computer communications by telephone may be either half-duplex or full-duplex. Radio communications is usually half-duplex, but there are exceptions. For example, in Amateur satellite operation, the transmission frequency is different than the reception frequency. This is a function of the way the satellite relays the signals. Under these circumstances, full-duplex operation is possible.

## DATA RATE

We're getting close to having the basic terms down pretty well. Before we begin to explore some of the specific digital techniques used for digital communications with amateur radio, it's important to look at speed and transmission methods.

### Words-Per-Minute

Telegraphers and early teletypewriter operators referred to the speed of their transmissions in terms familiar to typists. Rates of transmission were expressed in *words-per-minute* (wpm). Generally, every five characters counted as one word. In telegraphy, numbers counted as two characters because of their longer length in code. For scientific analysis of digital communications, however, a more accurate method of measuring speed was required. The unit selected was the baud.

### Baud

The *baud* is defined as the number of discrete conditions or signal events per second. It may be, but is not always, the same as bits per second. Since the baud is defined as a single quantity, it is proper to refer to speeds using the plural form, that is, 300 bauds rather than 300 baud. Although it has become common practice to use the singular form, we will use the plural form.

Every digital code can be broken down into individual bits. Regardless of how many bits form each character, or how many characters form a word, digital signals must be compared and analyzed using the baud rate. Most hobbyist computer modem communications occur at 300, 1200 or 2400 bauds. Rates on radio channels vary all the way from 45 bauds to 19,200 bauds and higher, with 300 and 1200 bauds being common for packet radio.

### Throughput

When comparing the relative speed of communications systems, you can't always compare just the baud rate. For example, one code consists of one start bit, five data bits, and one or more stop bits. Another code contains one start bit, seven data bits, and one or more stop bits. For the same number of characters, the 7-bit code requires the transmission of more bits than the 5-bit code. Therefore, a transmission using the 7-bit code sent at the same baud rate and containing the same characters will actually be somewhat slower in conveying information than a transmission using the 5-bit code, even though the actual number of bits sent per unit time is the same. This has an effect on *throughput*; that is, the effective transmission speed.

## ASYNCHRONOUS COMMUNICATIONS

While the overall transmission speed is important, it's also necessary to insure that each bit of information arrives at the proper time. In order for data to be received correctly, the station collecting the data must be kept in step with the transmitting station. Each element of the signal must be properly timed. Timing standards for each type of data communications have been established by agreement, but that's still not enough.



In many systems, the receiving station has no way of knowing when the transmitting station may begin to send data. When the beginning of a character can come at any time without meeting any other special requirements, the transmission is said to be *asynchronous*, or without synchronization.

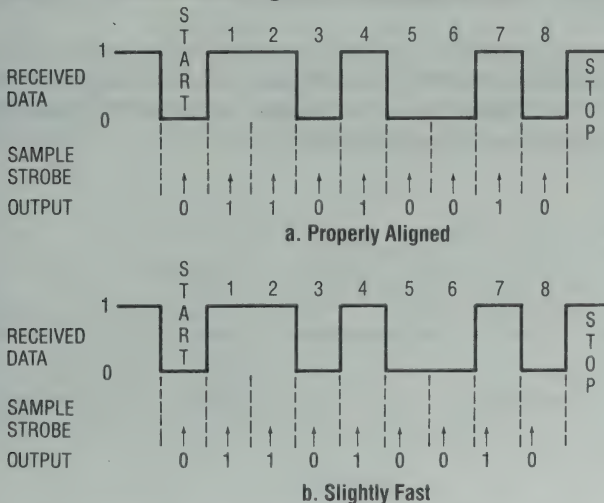
Even though the timing of each element is known ahead of time, there is still no way to predict when the signal will begin. The transmitting station needs to send some type of signal to indicate that transmission of data is about to occur. That sounds fairly simple until you think about it for a minute.

During on-line keyboard originated communications, data is transmitted on an irregular basis. A large group of characters may be followed by an equally long pause, then another character or two, and finally more characters. How is the receiving station to stay in synchronization under such conditions?

## Synchronization

Designers of original electro-mechanical teletypewriter machines solved the problem by beginning each character with a start signal. That signaled the receiving equipment that data was about to be transmitted. Essentially then, all signals after the start signal fall into predetermined time slots. If the sending and receiving equipment are properly adjusted, then all of the individual elements of the code following the start signal will be properly aligned or framed, as shown in *Figure 2-9a*. A limited amount of distortion caused by a motor running slightly fast or slow, or a crystal-controlled clock running off frequency, is tolerable as shown in *Figure 2-9b*. Since a new synchronization signal begins each character, the overall distortion is not cumulative from character to character.

**Figure 2-9. Asynchronous transmissions begin with a start bit and end with one or more stop bits. In *a*, the receiving station samples each bit at its midpoint, resulting in accurate decoding. In *b*, the receive clock is slightly fast, but the decoding remains accurate.**



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At the end of each character, one or more stop bits are also transmitted. The original need for such lengthy pauses at the end of each character was due to the wearing of gears in mechanical teleprinters. The stop bits allowed the machinery to reset to a known starting point before the next character was received.

SYNCHRONOUS COMMUNICATIONS

In *synchronous* communications, the transmitting and receiving station are synchronized to a single timing source. That's pretty easy to do when the terminals are located across the room from each other. They are always in step. Data can be transmitted in precise time slots and received accurately.

Synchronization

In some cases, synchronous systems are actually locked to an electronic clock or pulse generator. However, in many applications, including telephone and radio systems, another method is used. Each transmission is begun using a special sequence of bits called a start flag. The arrangement of bits in the flag is unique so it will not look like data. Special electronic circuits in the receiver extract the clock rate from the flag to synchronize the receiver with the transmitter. The data following the flag usually consists of several characters in sequence without start and stop bits.

Although a single start bit has been exchanged for a start flag with several bits, the extra time used by the flag is quickly made up by not having to send start and stop bits for each character when large amounts of data are transmitted. *Figure 2-10* compares asynchronous and synchronous transmissions.

Until recently, almost all amateur digital communications was asynchronous in nature. The advent of inexpensive computer chips have made the desirable synchronous systems more attractive. Both Amateur Teletypewriter Over Radio (AMTOR) and packet radio are examples of synchronous transmission methods used in amateur radio. (These are discussed in Chapter 3.) In the commercial field, high speed telephone modems also use synchronous technology.

Figure 2-10. In *a*, characters can come at any time for asynchronous transmission. In *b*, the characters are packaged together, one right after the other, for synchronous transmission.



a. Asynchronous

NOTE: sp means blank (space character)



b. Synchronous

Now that we know the basic terms used in data communications, we need to take a general look at the transmission methods commonly used to get the data from one point to another. The general techniques apply to both wired systems and radio systems.

## DATA COMMUNICATIONS BASICS

### Digital Information Over Telephone Lines

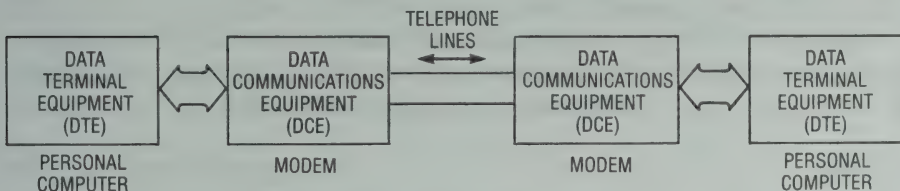
For the computer hobbyist, the most common way of hooking up to distant computers is via a telephone line. The serial data signal from a UART can be applied directly to a wired connection, but attempts to use this method result in numerous problems, particularly when large distances are involved. The on-off keying of the electrical signal from the UART is a pulsed direct current that will not pass through the telephone system. It would make it from your home connection to the central office, but usually no further. It would not be transferred into the long-distance network because there is not a direct current path past the central office in most telephone systems.

Standard telephone circuits are designed for analog transmission, not digital transmission. To optimize the voice network, filters are used throughout the telephone network to limit the bandwidth to the range of approximately 300 to 3400 hertz. We need a device to change the digital signal to an analog signal with a frequency that will pass through the telephone system. We'll find out what that device is in a moment.

### Data Terminal Equipment

A typical data communications system consists of several elements, as shown in *Figure 2-11*. First, there is the terminal. The *data terminal equipment* (DTE) is the device we use to transmit and receive information. It is present at both the transmitter and receiver ends.

**Figure 2-11. A typical data communications system is illustrated in block form. As shown, personal computers and modems are common elements used to implement the system.**





In the traditional sense, a terminal is the device used for sending and receiving information. It generally consists of a keyboard and some type of display. Initially, all terminals were mechanical in nature. They consisted of a myriad of gears and motors. A printing type output device was used. In fact, the earliest terminals were nothing but teletypewriter machines.

In later years, totally electronic terminals came into existence. As shown in *Figure 2-12*, it looks a bit like a computer with a television-like screen and an electronic keyboard. Generally, it won't do anything by itself because it must be connected to a computer system.

---

**Figure 2-12. Electronics terminals such as this Radio Shack® unit have replaced older mechanical units.**

---



### **Data Communications Equipment**

Second, we must interface the DTE to a device that will transform the computer's electrical pulses to a form that is acceptable to the communications channel. This device is called *data communications equipment* (DCE).

On the other end, the process is exactly the same, but reversed. The channel is connected to the DCE, which is interfaced to the DTE. In a full-duplex system, the path works equally well for both reception and transmission of data.

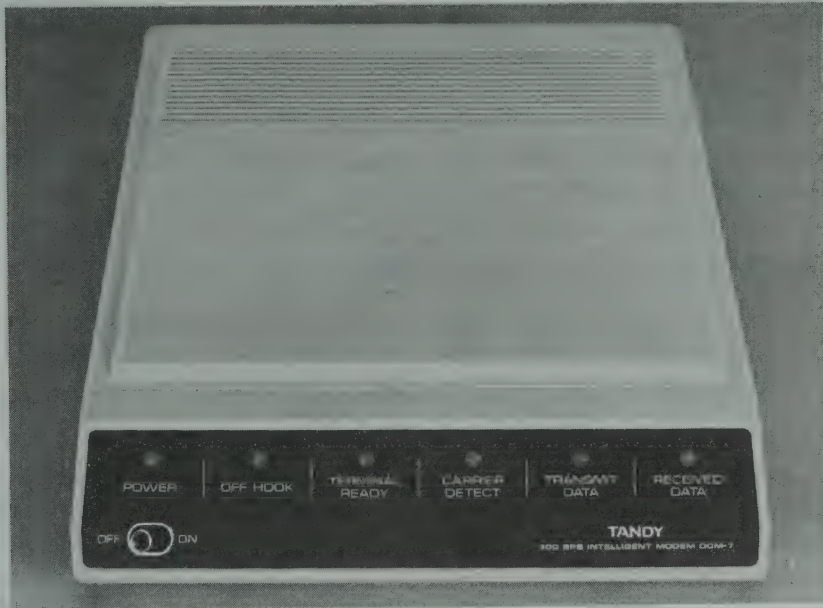
### **MODEMS**

The DCE we need for using a computer to transmit data over the telephone lines is called a modem. (The word *modem* is formed from the words *modulator* and *demodulator*.) A modem converts digital data into analog form so it can pass through the telephone system.

Modems come in many shapes and sizes. Some are external units like the one shown in *Figure 2-13*, and others are built on plug-in cards that can be installed inside your computer. Early modems relied on many discrete components. Today's technology puts much of the modem's electronics on a single integrated circuit at a fraction of the cost of modems ten years ago.

Most modems can be connected directly to a telephone line. Others can be acoustically coupled to the telephone handset. The telephone line is the actual channel over which all the data is sent and received.

**Figure 2-13.** This Tandy® modem available from Radio Shack is typical of the external DCE devices available for telephone computing.



## Basic Functions of a Modem

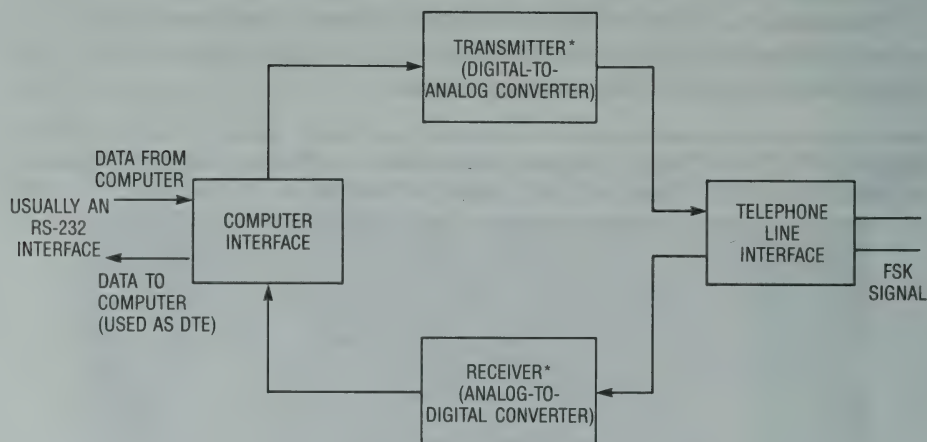
*Figure 2-14* illustrates the basic functions of a modem. Depending on the data rate or speed desired, one of several methods is used to modulate a carrier for data communications. The telephone company and other suppliers of professional modems offer many varieties depending on the specific application. We are going to concentrate first on low speed modems.

While the discussion that follows specifically refers to telephone modems, almost everything described applies equally well when the communications channel is a radio link. The differences are pointed out in Chapter 3.

## Frequency Shift Keying

The dc signal from the computer is applied to a tone generator. It generates one tone when the signal is at the zero or low level, and another tone when the signal is at the one or high level. This method of shifting between two tones is called *frequency shift keying* (FSK). The frequency of the tones is selected to optimize performance over a

**Figure 2-14. The basic components of a modem are shown in this block diagram.**



\*Using two separate sets of tones to allow full-duplex operation

voice grade telephone line. Typically, the two tones are separated in frequency by 200 hertz, with zeros transmitted at 1070 hertz and ones transmitted at 1270 hertz by the *originating* station.

(You may sometimes hear the terms *mark* and *space* used. A mark is equivalent to a one level and a space is equivalent to a zero level. These terms can be traced all the way back to an early printing telegraph unit. A pen was attached to a solenoid with a continuously moving paper tape placed underneath. When current flowed in the solenoid, the pen made a mark on the paper. When no current flowed, the pen was raised, creating a space on the paper.)

By agreement, the *answering* station transmits using a different tone pair to allow full-duplex operation. Zeros are transmitted at 2025 hertz and ones at 2225 hertz. These two pairs of tone frequencies are part of the Bell 103 standard which is the basis for most 300 bauds modems. Other standards exist, but are either no longer in common use, or are applied only for special purposes.

This type of modem is useful for signaling speeds of about 300 bauds. Actually, speeds twice as great may be possible under some conditions, but they aren't commonly used. Speed is limited by the available bandwidth of the communications channel. We can use higher speeds, but only if the channel will support a higher bandwidth. Fortunately there are other transmission methods that do not use as much bandwidth as the FSK system.



## Phase Shift Keying

By using a form of phase modulation, a higher data rate can be transmitted using a standard phone line. That's possible because phase modulation does not require as much bandwidth to transmit the same amount of data. Although several different forms of modulation can be used, *differential phase shift keying* (DPSK) is the method used in consumer grade modems operating at 1200 bauds. This method allows higher data rates for the same bandwidth by employing special techniques which encode two bits of data for each unit of signaling. (This is where bits per second and bauds are no longer equivalent. For example, if two bits are encoded in one baud, then 1200 bauds equals 2400 bits per second.) DPSK hasn't been used more in the past because it was costly to implement, but modern integrated circuits have broken through the price barrier. Another Bell standard, 212, defines the type of data transmission used for most hobbyist and business data communications at 1200 bauds. Synchronous communications techniques are used.

## Higher Speed Modems

Higher speed modems encode three or more bits per baud. A few years ago, modems operating at 1200 bauds were very expensive. Today, 2400 bauds is becoming very affordable, and even higher speed units are attractively priced. Unfortunately, the market place hasn't yet agreed upon a single standard for higher speed modems.

## PHYSICAL INTERFACES

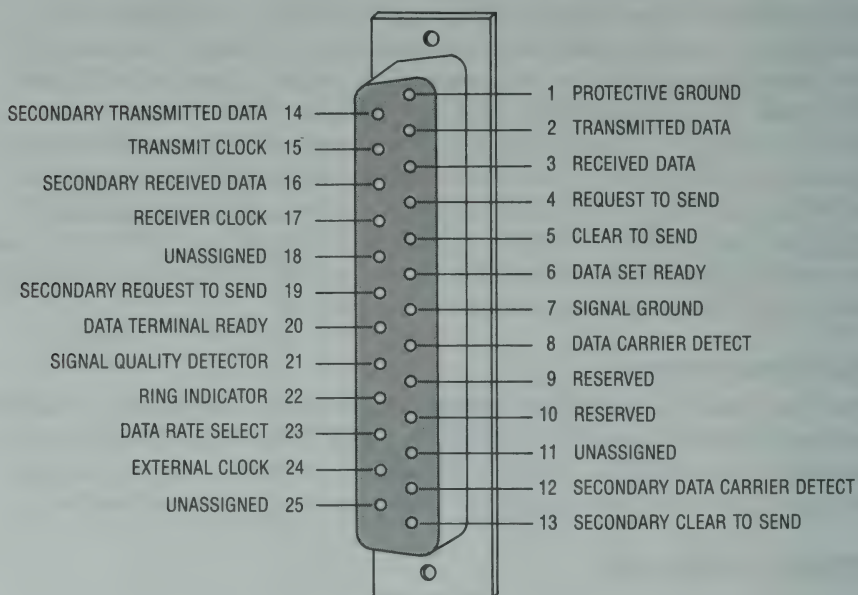
### RS-232

While many standards exist for connecting DCE and DTE equipment, perhaps the single most commonly used interface is the Electronics Industries Association (EIA) RS-232C specification. It addresses several different aspects of interfacing terminal and communications equipment. The mechanical characteristics are specified as well as the electrical signals across the interface. The function of each signal is defined. Even so, you might be surprised to learn that some of the things you thought were specified are not!

### DB-25 Connector

On many personal computers, a 25-pin connector, referred to as a DB-25 connector, is used for the RS-232 interface. *Figure 2-15* illustrates the physical configuration and identifies the pin-out. While the DB-25 has become a de facto standard, it is not specified in the RS-232C standard! The standard specifies assignment of signals to pin numbers and signal voltage levels, but it does not specify the physical configuration of the connector. Although all the signals are defined, you need to familiarize yourself only with a handful of the more common signals for most applications. Let's take a quick review of the signals you are likely to use.

**Figure 2-15.** You can use this diagram to locate the typical connections on a DB-25 female connector used for RS-232 cabling between a DCE and DTE.



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### **Signal to Pin Assignments**

We begin by noting that pin 1 is the protective ground pin, while pin 7 is signal ground. The interface will not work without pin 7 connected, while a disconnected pin 1 may not affect operation.

The transmitted data (TD) and received data (RD) pins are on pin numbers 2 and 3, respectively. The RS-232 signals are always referenced to the DTE equipment. This means the DTE transmits on pin 2 and receives on pin 3, but the DCE receives on pin 2 and transmits on pin 3.

Pins 4 and 5 have the request to send (RTS) and clear to send (CTS) signals, respectively. These two pins as well as pin 6, data set ready (DSR) and pin 20, data terminal ready (DTR) are pairs of signals that can be used for handshaking to insure that data is not lost in the transfer between the DTE and DCE. *Handshaking* refers to the way the DTE and DCE acknowledge each other.

A few more pins round out the list of those commonly encountered by the hobbyist. On pin 8, the received line signal detector, usually called data carrier detect (DCD or CD), indicates when a data signal is present based on the criteria established by the modem itself for carrier strength. Ringing on the line can be detected on pin 22, ring indicator (RI). This can be used to initiate auto-answering of incoming calls.

In some applications, only three wires are needed for data communications: signal ground, transmitted data, and received data. In other cases, the handshaking signals must either be present or the appropriate pins must be connected by jumpers before operation is allowed. The same is true of the data carrier detect signal. In some cases, handshaking is a function of the software being used. You may find that one program checks for these additional signals while another program does not.

## Non-Standard DTE/DCE Connections

While many computers use the DB-25 connector and pin connections, some manufacturers use a different connector, or modified pin connections, or both. Commodore computers are perhaps the best known for using odd connections. While RS-232 type signals are available, they are present on a user port connector that is not a DB-25. Additionally, the signal characteristics do not conform with most in the industry. Fortunately, adapters are available to overcome the problem. Some amateur radio equipment suppliers offer alternate connections for such computers so a special interface is not required.

Before going on to the fascinating world of digital communications with amateur radio, we need to address one more issue regarding basic data communications.

## THE PERSONAL COMPUTER AS A TERMINAL

Is a communications terminal a computer? No, because it doesn't have the necessary processing power and memory. Is a computer a communications terminal? Not by itself, but it can be with a little help from software. Your personal computer can run software to make it act like, or *emulate*, a communications terminal.

## Terminal Emulation Software

Communications programs for personal computers are actually terminal emulation programs. Some of them turn your computer into a generic terminal, while others make your computer act like one of the popular commercial brands of terminals. The Digital Equipment Corp. has several very popular terminals, including the VT-52<sup>TM</sup> and VT-100<sup>TM</sup>. Many terminal programs for computers implement these standards.

Depending on the make and model of your computer, creating a software program that allows it to emulate a generic terminal is pretty straightforward. Many computers already handle text in 7-bit or 8-bit form internally. Almost all machines have some way of connecting external peripherals. This can include disk drives, printers and modems.

## Programs Adjust Interface

While the internal communications in your computer occurs at very high speeds, data rates are typically reduced when communicating with external devices. As we discovered earlier, the external communications can take place in either serial or parallel. Both methods are common for printers, while serial is the usual method for other devices. Assuming that your computer has such capability, the terminal



program needs to shift the external serial port to the desired baud rate, and redirect the input and output so that information you type on the keyboard goes directly to the port at the desired speed. Incoming 7-bit or 8-bit data is routed directly to the screen so you can view it as it is received. In most computer languages, these steps can be accomplished with just a few simple commands.

## **Other Features**

Some computers use a modified form of standard codes so the proper translator must be included for the program to perform properly. The technique is a simple one involving the use of look-up tables, one for transmit and one for receive. Look-up table translators are important, because we can use a similar technique to write special programs that will decode amateur communications modes.

All of the other features common in terminal programs, like receive buffers, transfers to and from disk and tape, auto-dialing and so on, are not unique to data communications. The program can be very simple or laden with features. There are numerous variations available, both commercially and in the public domain, for just about any computer ever made. As you will see, the same program you use for telephone modem communications can be used for many amateur radio applications.

## **SUMMARY**

You should now have a good working knowledge of the basic terms used in data communications. If anything remains unclear, go back and re-read the explanations. In order to fully understand how amateur digital communications work, especially packet radio, you'll need to have this basic knowledge.

# Amateur Digital Communications

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## A LITTLE HISTORY

While the main focus of this book is on packet radio, hobbyists worldwide still enjoy earlier and more traditional forms of digital communications. By looking into the past, we can gain some understanding of the techniques that are applied to packet radio. Besides, many of the communications modes discussed can be implemented very easily on your home computer with very little investment. You may wish to experiment with them before taking on packet radio.

### Morse Code

It may be hard to believe that modern computer communications are based on Morse's telegraph system and later, Bell's telephone system, but they are. Everything from the earliest forms of telegraphy in the 1800s to modern land-line communications use the same communications path, some in exactly the same way.

In telegraphy, information was communicated over the path by turning an electrical current on and off in a special pattern. The clicking of the telegraph sounder unit was converted into a plain language message by the operator interpreting the spaces between the clicks. This method of data transmission was relatively slow and subject to human error.

When scientists proved that electrical signals could be transmitted directly through the air without using a connecting wire, operators used the Morse code for wireless transmission as well as wired transmissions. However, operators wanted a better method to transmit written communications and engineers searched for a more efficient system. They wondered if message transmissions could be accomplished using a device similar to a typewriter on each end? Surely that would be better.

### Baudot Code

The Morse code could not be used for operating a typewriter because its number of on-off conditions varied from one to five, and because of the varying lengths of the codes. Fortunately, a Frenchman named Emile Baudot had developed a code which used five on-off conditions, or bits, for every character.

### Why Five Bits?

In binary mathematics, each digit in a binary number has two possible conditions: on or off. Electrical and electronic circuits can easily assume one of two states — on or off — high or low, so they are ideal for manipulating binary digits (bits).

If only one circuit is available, it can represent bit position zero, which can represent either of two conditions. By adding a second circuit to represent bit position one, bit positions zero and one together can represent a total of four unique conditions. Each additional circuit doubles the number of conditions that can be represented. This is illustrated in *Figure 3-1*.

In other words, each additional bit position assumes a greater weight in a binary number or code. Bit position zero has a weight of one, bit position one has a weight of two, bit position two has a weight of four, bit position three has a weight of eight, and so on. *Figure 3-1* shows the decimal equivalent of each binary code.

### 32 Unique Conditions

With five bits available, a total of 32 conditions can be represented. That's enough to cover the 26 characters of the alphabet with a few left over. By defining one of the unique code groups as a shift character, the number of available characters is almost doubled, allowing the transmission of numbers and some punctuation. It still doesn't permit distinguishing between upper and lower case letters, so letter transmissions using a 5-bit code are in all upper case. The standard teleprinter code, which closely resembles the Baudot code, is given in *Figure 3-2*.

**Figure 3-1. The number of different conditions possible has a direct relationship to the number of bits used. Four bits can be used to represent 16 different conditions. Five bits would double the conditions to 32.**

	BIT POSITION → 3 2 1 0		DECIMAL EQUIVALENT
	VALUE OR "WEIGHT" OF EACH BIT POSITION → 8 4 2 1		↓
1 BIT REPRESENTS 2 CONDITIONS	0 0 0 0	$= 0 + 0 + 0 + 0 =$	0
	0 0 0 1	$= 0 + 0 + 0 + 1 =$	1
2 BITS REPRESENTS 4 CONDITIONS	0 0 1 0	$= 0 + 0 + 2 + 0 =$	2
	0 0 1 1	$= 0 + 0 + 2 + 1 =$	3
3 BITS REPRESENTS 8 CONDITIONS	0 1 0 0	$= 0 + 4 + 0 + 0 =$	4
	0 1 0 1	$= 0 + 4 + 0 + 1 =$	5
	0 1 1 0	$= 0 + 4 + 2 + 0 =$	6
	0 1 1 1	$= 0 + 4 + 2 + 1 =$	7
4 BITS REPRESENTS 16 CONDITIONS	1 0 0 0	$= 8 + 0 + 0 + 0 =$	8
	1 0 0 1	$= 8 + 0 + 0 + 1 =$	9
	1 0 1 0	$= 8 + 0 + 2 + 0 =$	10
	1 0 1 1	$= 8 + 0 + 2 + 1 =$	11
	1 1 0 0	$= 8 + 4 + 0 + 0 =$	12
	1 1 0 1	$= 8 + 4 + 0 + 1 =$	13
	1 1 1 0	$= 8 + 4 + 2 + 0 =$	14
	1 1 1 1	$= 8 + 4 + 2 + 1 =$	15

0 = OFF  
1 = ON



**Figure 3-2. A 5-bit teleprinter code. Using one of the 5-bit codes for LTRS and another for FIGS allows the letter codes to be used again for a special set of characters.**

Binary Bit Positions						Letters (LTRS)	Figures <sup>2</sup> (FIGS)
	0	1	2	3	4		
Baudot Code Positions <sup>1</sup>						Letters (LTRS)	Figures <sup>2</sup> (FIGS)
Start	1	2	3	4	5	Stop	
	1	1	0	0	0	A	—
	1	0	0	1	1	B	?
	0	1	1	1	0	C	:
	1	0	0	1	0	D	\$
	1	0	0	0	0	E	3
	1	0	1	1	0	F	!
	0	1	0	1	1	G	&
	0	0	1	0	1	H	#
	0	1	1	0	0	I	8
	1	1	0	1	0	J	Bell
	1	1	1	1	0	K	(
	0	1	0	0	1	L	)
	0	0	1	1	1	M	.
	0	0	1	1	0	N	,
	0	0	0	1	1	O	9
	0	1	1	0	1	P	0
	1	1	1	0	1	Q	1
	0	1	0	1	0	R	4
	1	0	1	0	0	S	'
	0	0	0	0	1	T	5
	1	1	1	0	0	U	7
	0	1	1	1	1	V	;
	1	1	0	0	1	W	2
	1	0	1	1	1	X	/
	1	0	1	0	1	Y	6
	1	0	0	0	1	Z	"
	0	0	0	0	0	Blank <sup>3</sup>	
	1	1	1	1	1	Letters shift (LTRS) <sup>3,4</sup>	
	1	1	0	1	1	Figures shift (FIGS) <sup>3,5</sup>	
	0	0	1	0	0	Space <sup>3</sup>	
	0	0	0	1	0	Carriage Return <sup>3</sup>	
	0	1	0	0	0	Line Feed <sup>3</sup>	

## NOTES:

<sup>1</sup> 1 = current on; 0 = current off<sup>2</sup> North American Teletype Commercial Keyboard<sup>3</sup> Non-printing characters<sup>4</sup> Selects LTRS character set. Receipt of LTRS code causes all following codes to be interpreted as letters.<sup>5</sup> Selects FIGS character set. Receipt of FIGS code causes all following codes to be interpreted as numerals, punctuation marks, or special characters.

## TELETYPEWRITER OPERATION

Teletypewriters use the same current loop circuit as the telegraph. Transmission is accomplished by interrupting the flow of current in the circuit in step with the Baudot code. Let's take a closer look at how it works.

*Figure 3-3* illustrates the operation of a teletypewriter with an electromechanical encoding and decoding mechanism. Although the teletypewriter at both ends can have both sending and receiving capabilities, only one way is shown for simplicity.

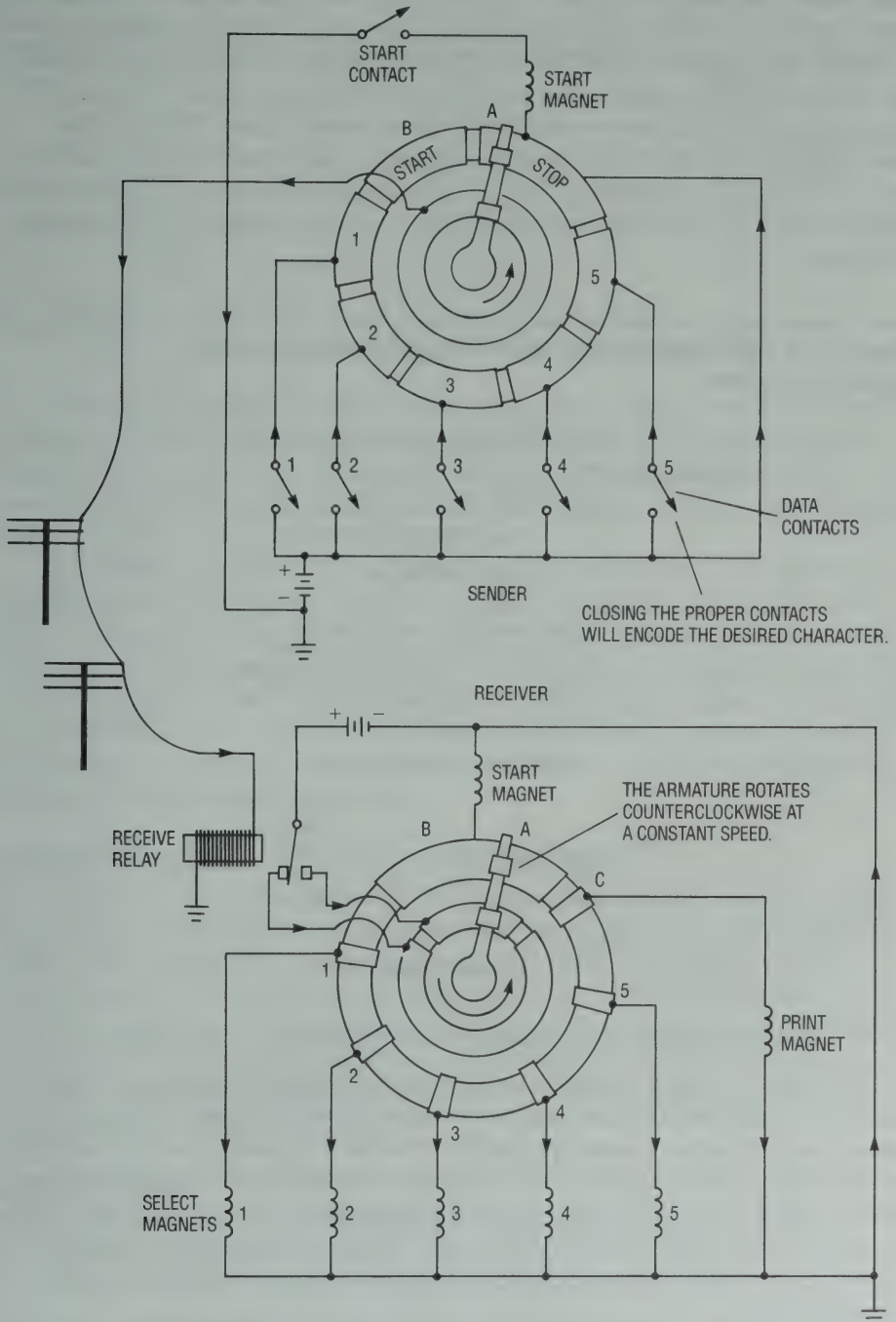
An electric motor provides rotation to the moving contact, called the armature, of each unit when its clutch is engaged. The diagram shows both units in an idle condition with the sender's armature on the stop contact. The sender's clutch is disengaged. The receiver's clutch is held disengaged by current from the sender's battery through the sender's stop contact, the transmission line, and the receive relay. When a key is pressed on the sending unit, the sender's start contact and one or more of the data contacts are closed. Closing the start contact energizes the start magnet which engages the sender's clutch and the armature rotates counterclockwise. As soon as the sender's armature moves from the stop contact to the start contact, the receiver's receive relay de-energizes. In other words, the sender sends a start bit to the receiver by dropping the line. The receiver's clutch engages and the receiver's armature begins to move in a counterclockwise direction at approximately the same speed as the sender's.

Let's assume the R key was pressed. According to *Figure 3-2*, data contacts 2 and 4 are closed, so they are in the on condition and data bits 1, 3, and 5 are in the off condition. As the armature moves over contact 1, nothing happens. As the armature moves over contact 2, current from the sender's battery flows through the armature, the transmission line, and the receiver's receive relay which energizes the relay. The receiver's armature is also moving over contact 2 so the receiver's battery current flows through contact 2 and select magnet 2 to latch the select magnet. The same operations occur as the armatures continue to rotate, so select magnets 2 and 4 are latched when the receiver's armature moves over contact C. Current through contact C energizes the print magnet which causes the printing mechanism to print an R on the receiver's paper. The armatures continue moving until each reaches the idle position. The sender sends a stop bit which disengages the receiver's clutch and both armatures stop moving. They remain in this position until another key is pressed.

Notice that each transmission begins with a *start bit*, which is followed by five *data bits*, and concludes with a *stop bit*. Notice also that after both motors are started, there is nothing to synchronize the armatures. Over a period of time, they would drift far enough apart so that errors would occur; however, satisfactory results were obtained in the short time needed to transmit the 5-bit code.

By substituting a radio transmitter in place of the wired channel, the same information can be conveyed in a wireless fashion. The on-off keying from the teletypewriter simply keys the transmitter in the same way as a telegraph key does. On the receiving end, an electronic circuit changes the on-off tone coming from the receiver into an electric current to drive the teletypewriter.

**Figure 3-3.** This is a schematic representation of a mechanical Baudot teletypewriter system's operation.



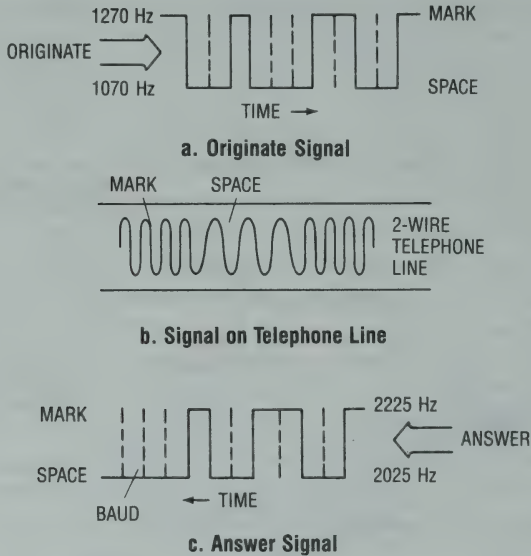
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## FREQUENCY SHIFT KEYING FOR RADIO TRANSMISSION

Radio experimenters found that on-off keying was subject to a great amount of interference from static. While searching for a way to overcome these problems, they began applying *frequency shift keying* (FSK). As shown in *Figure 3-4* for full-duplex telephone communications, the on and off conditions of the signal are represented by two different tone frequencies. The mark frequency for the originate signal is 1270 Hz, while the space frequency is 1070 Hz. For the answer signal, 2225 Hz is the mark frequency and 2025 Hz is the space frequency. Each combination of mark and space frequencies is separated by 200 Hz. Since one of the tones is always present on the receiving end, it has a quieting effect on the radio and results in better reception of the data.

**Figure 3-4. FSK frequencies for full-duplex telephone line communications.**



Source: Installing Your Own Telephones, Master Publishing, Inc., Copyright © 1987.

For radio use, the two frequencies are spaced with variable spacing, in some cases, closer than the 200 hertz spacing of the telephone FSK tones. Typical early radio systems relied on a wider spacing of 850 hertz. While some activity, notably by the U.S. Navy, still occurs using an 850 hertz shift, most commercial applications now use either a 425 or 170 hertz shift to conserve bandwidth. Amateur radio operators almost exclusively use the 170 hertz shift. Even narrower shifts are possible. *Figure 3-5* provides a reference chart for the mark and space frequencies of the various spacings.

**Figure 3-5. Mark and space frequencies for FSK spacing (U.S. Standard).**

Spacing	Mark	Space
170 Hz	2125 Hz	2295 Hz
170 Hz	1275 Hz	1445 Hz
200 Hz	1270 Hz	1070 Hz Originate
200 Hz	2225 Hz	2025 Hz Answer
425 Hz	2125 Hz	2550 Hz
850 Hz	2975 Hz	2125 Hz
850 Hz	1275 Hz *	2125 Hz

\*British Standard

Rather than pulsing dc over dedicated telegraph lines, frequency shift keying is also used to send teletypewriter signals as audio tones over voice grade telephone lines in the same manner as we discussed for direct computer communications. This same system is still in use today for much of the teletypewriter data communications taking place by modem over standard telephone lines.

As mentioned in Chapter 2, computer hobbyists use two-tone FSK modems for communications over regular voice grade telephone lines when operating at speeds below 600 bauds. It's also the method of choice for data communications on VHF frequency bands by amateurs. The modem's output signal can be applied directly to the audio input of an inexpensive FM transmitter. The maximum speed possible with FSK transmissions is a function of the bandwidth available on the radio channel. That works out to approximately 600 bauds, which is the same as for communications over a voice grade telephone line.

### PHASE SHIFT KEYING FOR RADIO TRANSMISSION

Like telephone lines, higher speeds of 1200, 2400, and even 4800 bauds are possible using radio transmission by utilizing differential phase shift keying. Recall that this method allows higher data rates for the same bandwidth by employing special techniques which encode more than one bit of data for each unit of signaling. This allows the same channels to be used at higher speeds. In the past, it was significantly more costly to encode data transmissions using DPSK; however, recent developments in low cost integrated circuits have narrowed the gap so that high speed modems are now attractively priced.

### RADIO MODEM

Teletypewriter operators call the interface between their equipment and the telephone line a *terminal unit* (TU). Today, many hams call the hardware interface between their computer and radio a *computer patch* or *radio modem*. Regardless of the name, the function is the same — to interface the data terminal equipment to the communications channel. It is still a piece of data communications equipment using the same techniques as its telephone modem cousin.

The development of an effective data transmission method for both radio and telephone work is important. It remains the basis for much of the data transmission taking place today, though new and improved codes and methods make the present system even more effective.

## TYPICAL AMATEUR TRANSMISSION SPEEDS

### Mechanical DTE

Remember that the teletypewriter uses an asynchronous, serial form of transmission. The characters can begin at any time, and a start bit signals the beginning of each character. Stop bits allow time for mechanical printers to come to rest before receiving another character. Early teletypewriter systems typically operated at approximately 60 words-per-minute (wpm), or about 45 bauds — about as fast as a reasonably good typist. The main limitation was the accuracy of the gears and motors. As the ability to machine parts to a higher tolerance was developed, mechanical teleprinters rose in speed to 75 wpm, then 100 wpm. Today, most amateur work still takes place at these speeds.

### Punched Paper Tape

Since even a good typist usually doesn't type much faster than 60 wpm, and usually less than 100 wpm, the available speeds could easily keep up with on-line sending. However, because most typists could not utilize the full speed, a punched paper tape system was developed so that messages could be typed off-line and stored on paper tape. When the message was finished, a tape reader attached to the teleprinter could read the paper tape for transmission at maximum speed. Even some computer systems in the 1970s relied on punched paper tape for program storage! A punched paper tape can still serve as a good learning tool since it allows you to see the code for each character. Each *on* bit in a character is represented by a hole and each *off* bit by no hole.

While almost all amateur activity conforms to accepted standards, there are some slight variations in the speed of Baudot transmissions, especially in other countries. In some cases, the actual baud rate is slightly different; in other cases, the length of the stop bits varies from the U.S. standard. In many instances, however, the signal framing is close enough to permit proper decoding of the information.

### ASCII

In the 1950s, computers began to make their mark, particularly in the scientific community. It soon became evident that the character set available with Baudot code was too restrictive. A decision to create a new code resulted in the American Standard Code for Information Interchange (ASCII). The code, shown in *Figure 3-6*, is similar to Baudot, but consists of seven information (data) bits rather than five. The additional two bits makes it possible to define 128 unique characters. That allows upper and lower case letters, numbers, a wide variety of punctuation, and a few special symbols. Additionally, the eighth bit can be used for a simple form of error checking called parity. We'll discuss parity a little later.



**Figure 3-6. This is the American Standard Code for Information Interchange (ASCII).**

Bit Position														
							0	1	0	1	1	0	0	1
							0	0	1	1	1	1	0	0
1	2	3	4	5	6	7	1	1	1	1	0	0	0	0
0	0	0	0				@	P	'	p	0	sp	NUL	DLE
1	0	0	0				A	Q	a	q	1	!	SOH	DC1
0	1	0	0				B	R	b	r	2	"	STX	DC2
1	1	0	0				C	S	c	s	3	#	ETX	DC3
0	0	1	0				D	T	d	t	4	\$	EOT	DC4
1	0	1	0				E	U	e	u	5	%	ENQ	NAK
0	1	1	0				F	V	f	v	6	&	ACK	SYN
1	1	1	0				G	W	g	w	7	'	BEL	ETB
0	0	0	1				H	X	h	x	8	(	BS	CAN
1	0	0	1				I	Y	i	y	9	)	HT	EM
0	1	0	1				J	Z	j	z	:	*	LF	SUB
1	1	0	1				K	[	k	{	;	+	VT	ESC
0	0	1	1				L	\	l		<	,	FF	FS
1	0	1	1				M	]	m	}	=	-	CR	GS
0	1	1	1				N	^	n	~	>	.	SO	RS
1	1	1	1				O	_	o	DEL	?	/	SI	US

## Extended ASCII

Most modern computer systems use an extended form of ASCII that uses eight data bits because most computers handle data in 8-bit bytes (or multiples of eight). With eight data bits, 256 characters can be defined. Many computer designers have defined the additional 128 codes available beyond ASCII's 128 combinations as special graphics characters. Unfortunately, there is no standard for these characters. Also, some designers have taken liberties with the basic ASCII character set itself. In Commodore computers, for example, the positions of the upper and lower case alphabetic characters are shifted.

When connecting different systems together via radio or telephone link, it is very important to remember that pure ASCII uses seven bits, not eight.

## Transmissions Using ASCII

For many years, amateurs were restricted to the use of Baudot code. In fact, since many stations, including the Federal Communications Commission monitoring stations, were not equipped with teleprinter equipment, data transmissions had to be

identified every ten minutes using Morse code! That requirement was dropped just a few years ago. Later, authorization was given for ASCII and other codes to be used on a case-by-case basis. Current regulations allow any widely used code to be used as long as bandwidth limitations are honored.

Other than the difference in the number of characters available as a result of increasing the number of information bits, ASCII transmission is accomplished in the same way as Baudot and teletypewriter code transmissions.

In the early days of ASCII, mechanical terminals were still the norm. A speed of 110 bauds was most common, with a few 300 bauds units available. Once the gears were replaced by totally electronic terminals, much higher speeds became common place. In a local environment, speeds in the tens of thousands of bauds are often used. Over radio circuits, 110 and 300 bauds still predominate, with some work done at 1200 bauds and higher.

Interestingly, very little use of ASCII is made in radio transmissions. Commercial shortwave services still rely on Baudot code. Amateur radio enthusiasts continue to make some use of the code. It's very easy to do. In fact, you could use a standard telephone modem to do the job, even though the tone frequencies chosen by amateurs are different than those used on telephone circuits. Recall that amateurs use a 170 hertz difference between the tones, but standard telephone modems use a 200 hertz difference.

If you can find an amateur ASCII transmission on one of the short wave frequency bands such as 20 meters (14 MHz), it should be possible to properly decode it using the same modem and terminal emulation software you use for telephone data communications. Keep in mind that most telephone data communications are full-duplex while radio communications are usually simplex or half-duplex.

## OTHER CODES

Other codes have been created over the years in 5-, 6-, 7- and 8-bit versions. The Extended Binary Coded Decimal Interchange Code (EBCDIC) is an example of an 8-bit code. Other examples are typesetter's codes and business codes. You are unlikely to run across these codes in your hobby activities, but it's good to know they exist.

## THE SEARCH FOR ERROR FREE COMMUNICATIONS

Data specialists and hobbyists are constantly looking for ways to insure the integrity of the received information. Some information transmitted over telephone lines and dedicated hardwired circuits is very critical. Financial transactions, for example, must be completely accurate. You wouldn't be very happy if you had \$9000 in the bank, but the computer transformed it into \$1000 because one or two bits of data were lost in transmission!

When the transmission path is not of consistently high quality, errors can creep into the received information very easily. Radio circuits are notorious for fading, interference, phase shift, and other problems not normally encountered on a telephone circuit.

## Eighth Bit Parity

As mentioned earlier, the eighth bit is sometimes used as a simple form of error checking called *parity*. During transmission, the sending station determines how many ones are contained in the seven information bits. If even parity is used, the eighth bit is calculated so that the total number of ones in the transmitted character will be even. If the number of ones in the seven data bits is already even, the parity bit is set to zero. If the number of ones in the seven data bits is odd, the parity bit is set to one so that the total number of bits set to one is even. Even parity is illustrated in *Figure 3-7a*. Odd parity is similar, but results in the total number of ones always being an odd number as shown in *Figure 3-7b*.

**Figure 3-7. In *a* parity bits are calculated and inserted for even parity. In *b*, parity bits are calculated and inserted for odd parity.**

	PARITY BIT ↓							
DATA WORD #1	1	1	1	0	1	0	1	1
DATA WORD #2	1	0	1	0	1	0	1	0
DATA WORD #3	0	0	0	1	1	0	1	1
DATA WORD #4	1	0	0	0	0	0	0	1
	d <sub>7</sub>	d <sub>6</sub>	d <sub>5</sub>	d <sub>4</sub>	d <sub>3</sub>	d <sub>2</sub>	d <sub>1</sub>	d <sub>0</sub>

**a. Even Parity Requires an Even Number of Ones**

	PARITY BIT ↓							
DATA WORD #1	0	1	1	0	1	0	1	1
DATA WORD #2	0	0	1	0	1	0	1	0
DATA WORD #3	1	0	0	1	1	0	1	1
DATA WORD #4	0	0	0	0	0	0	0	1
	d <sub>7</sub>	d <sub>6</sub>	d <sub>5</sub>	d <sub>4</sub>	d <sub>3</sub>	d <sub>2</sub>	d <sub>1</sub>	d <sub>0</sub>

**b. Odd Parity Requires an Odd Number of Ones**

## Other Parity or No Parity

Several other forms of parity also exist. One example is the mark/space parity, where the parity bit is set so that it is always either a mark signal or a space signal.

Often, no parity is used. If so, the receiving end simply ignores the value of the eighth bit if only seven bits are being used for data. However, sometimes all eight bits are used for data with no parity. In this case, the receiving end reads all eight bits as data. It should be apparent that the transmitting and receiving ends must agree on how the eight bits are to be used.

When parity is used, the receiving station can mark data that does not pass the parity test as potentially bad data. In radio transmission, parity does very little to insure the accuracy of received data. The problem is that the parity bit is just as subject to interference or distortion as the data bits. That means perfectly good data can be received with the parity bit erroneously set, or bad data can arrive with the parity bit properly set.



## Amateur Teletypewriter Over Radio

One successful method for virtually guaranteeing valid information on marine and amateur radio circuits is a special form of the Baudot code known as *Teletypewriter Over Radio* (TOR). The amateur version is called AMTOR. TOR and AMTOR are used in synchronous communications. A communications unit that uses AMTOR is shown in *Figure 3-8*.

**Figure 3-8. A commercially manufactured AMTOR unit.**



*Courtesy of Advanced Electronic Applications*

### **TOR Code**

The actual TOR code has its roots in Baudot code. Seven bits, rather than five, are used and the bits are assigned in a unique fashion. In the TOR code, every character must consist of four mark tones and three space tones. This is illustrated in the AMTOR code shown in *Figure 3-9*. This reduces the number of possible code combinations to 35. The first 32 codes parallel the Baudot code, and the remaining combinations are designated as service information signals. On the receiving end, any character that doesn't pass the "four mark, three space" test is rejected as invalid.

### **TOR Communications**

Here's how a typical TOR communications takes place: The originating station is called the *master* station and the receiving station is called the *slave* station. The roles of master and slave can be easily reversed, as we will see in a moment. The master station begins transmitting the specially assigned four-letter callsign of the other station. Since this is synchronous communications, specific time windows are assigned for the transmitting and receiving stations.

The callsign of the slave station is transmitted in three-character blocks. After each three-character transmission, the master station pauses to listen for an acknowledgment from the slave station. Upon recognizing its callsign, the slave station responds with a ready signal. Once the acknowledgment is received by the master station, the communications path is established and information can flow from the master to the slave. The information is sent in the same type of three-character blocks used to establish contact.

**Figure 3-9. The AMTOR code is made up of four marks and three spaces.**

Letters Case	Figures <sup>2</sup> Case	AMTOR Code <sup>1</sup> Bit Number						
		6	5	4	3	2	1	0
A	—	1	0	0	0	1	1	1
B	?	1	1	1	0	0	1	0
C	:	0	0	1	1	1	0	1
D		1	0	1	0	0	1	1
E	3	1	0	1	0	1	1	0
F		0	0	1	1	0	1	1
G		0	1	1	0	1	0	1
H		1	1	0	1	0	0	1
I	8	1	0	0	1	1	0	1
J	BELL	0	0	1	0	1	1	1
K	(	0	0	1	1	1	1	0
L	)	1	1	0	0	1	0	1
M	.	0	1	1	1	0	0	1
N	,	1	0	1	1	0	0	1
O	9	1	1	1	0	0	0	1
P	0	0	1	0	1	1	0	1
Q	1	0	1	0	1	1	1	0
R	4	1	0	1	0	1	0	1
S	'	1	0	0	1	0	1	1
T	5	1	1	1	0	1	0	0
U	7	1	0	0	1	1	1	0
V	=	0	1	1	1	1	0	0
W	2	0	1	0	0	1	1	1
X	/	0	1	1	1	0	1	0
Y	6	0	1	0	1	0	1	1
Z	+	1	1	0	0	0	1	1
<b>Both Cases</b>								
Carriage Return		1	1	1	1	0	0	0
Line Feed		1	1	0	1	1	0	0
Letters Shift		1	0	1	1	0	1	0
Figure Shift		0	1	1	0	1	1	0
Space		1	0	1	1	1	0	0
Blank		1	1	0	1	0	1	0
Control Sig 1		1	1	0	0	1	0	1
Control Sig 2		1	1	0	1	0	1	0
Control Sig 3		1	0	0	1	1	0	1
Idle Sig Beta		0	1	1	0	0	1	1
Idle Sig Alpha		0	0	0	1	1	1	1
Signal Reception		1	1	0	0	1	1	0

**NOTE:**

<sup>1</sup> Remember that AMTOR is a 100 bauds synchronous transmission system. There must always be a ratio of four marks (or ones) to three spaces (or zeros) in each character.

<sup>2</sup> CCITT Standard International Telegraph Alphabet #2

If even a single error is detected in a block of received information, the slave station does not print the data, but issues a repeat request to the master. This particular part of the TOR system is sometimes called the *automatic repeat request* (ARQ) mode. Only a block that is considered free of errors is allowed to pass to the screen or printer.

A special character sequence allows the two stations to reverse roles so that communications can flow in the opposite direction. Control of the path is accomplished using three special codes.

This system operates by international standard at 100 bauds. The effective speed or actual throughput is much less. Under fairly good conditions, throughput is roughly the same as standard 45 bauds teletypewriter transmissions.

### **Chirping Birds**

The TOR transmission method uses the same techniques as standard Baudot and ASCII transmissions, but the short, bursty nature of the transmissions has a distinctive sound when heard on a radio circuit. It is often described as two birds chirping back and forth!

The integrity of the data is very high, but not 100 percent. It is still possible to accidentally create a block of information that checks valid on the receiving end. For most message applications, the accuracy exceeds normal requirements for reliability.

Since the sending and receiving station must be synchronized for data exchange, it is impossible to broadcast the same information, error-free, to more than one station at a time. Other stations can monitor the transmission, but the transmitting station has no way of knowing whether these other stations correctly received the transmitted information.

### **Forward Error Correction**

While it's not a foolproof method of overcoming the problem, another form of TOR, called *Mode B*, allows for multi-station transmission of information. Mode B is a *forward error correction* type of transmission. Each character is sent twice, with the second transmission of the character occurring after four more characters have been sent. On the receiving end, only characters meeting the "four mark, three space" test are considered valid. When both transmissions of a particular character match, it is printed on the screen. If one passes the test, but the other does not, the one passing the test is printed. If both characters fail the test, a blank or error character is printed on the screen. There is no pause in Mode B transmissions, so they sound very similar to ASCII and Baudot transmissions.

Since the chances are against fading and interference occurring during both transmissions of the same character, Mode B TOR broadcasts are an efficient way to disseminate general information to more than one station. Mode B transmissions are also sent at 100 bauds. Since each character is sent twice, the effective speed is close to 50 bauds.



The amateur implementation of TOR was accomplished by a British amateur in the early 1980s. It was just beginning to attract a large amount of interest in the ham radio community when packet radio came along. The goal of both systems is to provide error free communications. In an absolute sense, packet radio has the potential for doing a better job, but in day-to-day operation, AMTOR is often overlooked as an extremely effective way to pass routine messages around the world. In the United States, Novice class amateurs are permitted to operate all available digital modes on a reserved portion of the 28 MHz (10 meter) Amateur Radio band. This gives them the chance to experiment with Baudot, ASCII and AMTOR codes as well as packet.

## HARDWARE CONNECTIONS FOR RADIO COMMUNICATIONS

The hardware considerations are slightly different for each mode of operation. If you keep in mind during this discussion that the interface used for radio operation is just a variation on the telephone modem, you should be able to understand the basic operation. We need the same types of equipment for amateur digital communications via radio as we need for computer telephone data communications.

### Amateur DCE

Regardless of what type of code is used, virtually all data modes will require some type of data communications equipment (DCE). Remember, in amateur circles it may be called a radio modem, computer patch, or terminal unit.

First, let's concern ourselves with receiving data. Regardless of whether you wish to decode Morse code, packet radio, or something in-between, you must convert the tone or tones coming from your receiver into signals your computer or other DTE can accept.

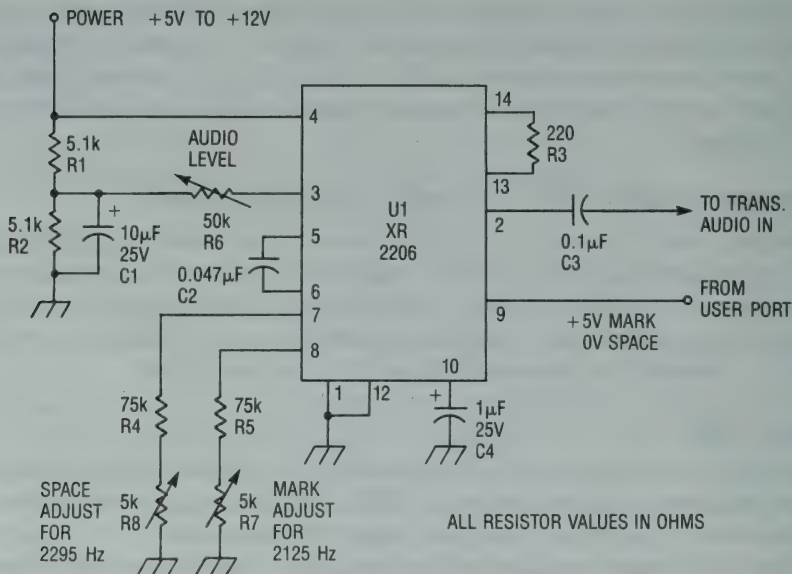
While terminal units of the 1950s and 1960s relied on vacuum tubes and discrete components, modern radio modems often utilize the same integrated circuits designed for telephone modems. In its simplest form, the entire modem is reduced to a single chip. The first computer patches consisted of little more than this type of circuit. Many amateurs have experimented at one time or another with an interface built around the Exar™ XR-2206™ and XR-2211™. The transmit or modulator part of one such interface is shown in *Figure 3-10*. Such circuits work amazingly well when the communications channel is free from fading and interference.

Commercially manufactured interfaces based on this simple technology retail for significantly less than \$100. Higher priced units employ additional circuits that help under adverse conditions. A typical unit is shown in *Figure 3-11*.

### Filtering for Better Data

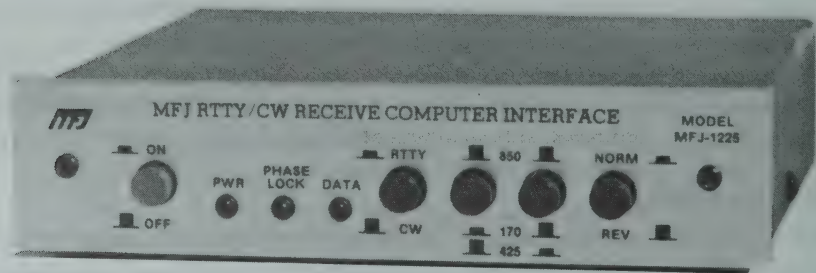
When receiving data over a radio circuit, a lot of unwanted signals can creep in. Sometimes more than one station is transmitting on the same frequency or adjacent frequencies, resulting in interference. Perhaps the biggest single problem is atmospheric noise. Noise tends to look exactly like data, resulting in the possibility for numerous errors. More elaborate and more expensive units employ extensive filtering to help reduce interference and lift the desired data signals above the noise.

Figure 3-10. A simple modem can be constructed from just one or two integrated circuits. Shown here is the modulator function using one IC.



Courtesy of QSKY Publishing

Figure 3-11. Computer interface for RTTY and CW.



Courtesy of MFJ Enterprises, Inc.

## Desirable Features

When sending data over VHF and UHF radio circuits utilizing an FM radio transceiver, there is no need to tune the receiver to properly decode the transmitted information. You only have to set the radio to the proper channel by dialing it in. On high frequency circuits, it is necessary to correctly tune the receiver since channelized communications is not normally used. An experienced operator can sometimes do this effectively by ear, but most beginners find it difficult. Therefore, another distinguishing characteristic of a better radio modem is an accurate tuning indicator. Today, these generally take the form of light-emitting diode bar graphs, but oscilloscope patterns and tuning eyes have been used over the years. An example of a more sophisticated radio modem is shown in *Figure 3-12*.

## Interfacing the Transmitter

Some units are designed exclusively for use with amateur standards such as the 170 hertz shift, while others include filtering for commercial shifts, usually at additional cost. The same is true on the transmit side of the unit. Usually, units with greater versatility command a higher price.

Interfacing for transmission is relatively simple and is implemented in much the same fashion for both inexpensive and higher priced units. Another possible difference between units is the ability to connect more than one transceiver or transmitter/receiver combination to a single computer.

Generally speaking, a standard radio modem requires a fair amount of interfacing to properly connect it to your computer and radio equipment. *Figure 3-13* shows a rear view of a typical radio modem. The radio modem performs the basic transformations from audio signals to pulses for receive and conversion from computer pulses to audio tones for transmit. It also handles the tasks of turning the transmit line on and off on command. Unfortunately, there really are no standards for any of this interfacing.

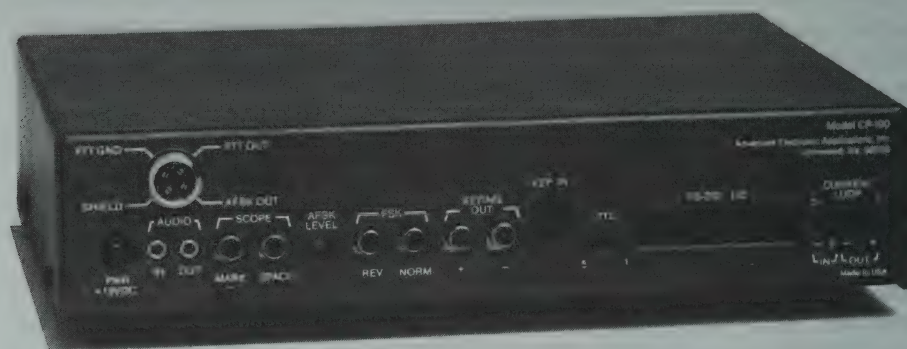
**Figure 3-12. A computer patch is the radio equivalent of a telephone modem.**



*Courtesy of Advanced Electronic Applications*



**Figure 3-13.** The connections for a transmitter and receiver are located on the back of a computer patch.



*Courtesy of Advanced Electronic Applications*

## Dedicated DTE

On a telephone-based network, many varieties of DTEs are used, though the personal computer is perhaps the most popular for hobbyists. Amateur Radio operators are just a special form of hobbyists. Since personal computers are the DTE of choice, let's devote most of our attention to using them for Amateur data communications.

It is necessary to have either a self-contained device that can interpret the code being transmitted connected directly to the interface, or have a personal computer with the proper software to properly translate the code into something the computer can display.

## Your Computer — The Flexible DTE

The majority of available software packages are designed to be used with popular personal computers. For several years, Commodore computers dominated the amateur market place. Not surprisingly, the interface manufacturers made their products easy to connect to Commodore machines. Don't let that discourage you though. Almost every popular home computer has been successfully used on the Amateur bands for data communications. In fact, many Radio Shack TRS-80 Model I computers were among the very first used! Today, PC clones, like the Tandy® Model 1000 series, are becoming the most popular computers for the ham shack.

Regardless of what type of machine you interface to, you'll still need some special software. In most cases, the software will adapt your personal computer to a variety of digital communications modes. The program may be on disk, tape, or a plug-in cartridge. A programmed plug-in cartridge is shown in *Figure 3-14*.

Earlier, we briefly discussed using personal computers for radio-based ASCII communications. It's worth repeating that a standard terminal emulation program for your computer is all that's needed in terms of software to receive such transmissions.

**Figure 3-14.** Software that allows your personal computer to send and receive Amateur data modes is available both commercially and in the public domain. A programmed plug-in cartridge (including built-in radio modem) is illustrated.



*Courtesy of Advanced Electronic Applications*

Little or no conversion is necessary. Standard data rates are used, usually 110 and 300 bauds. Decoding Baudot and other teletypewriter-like codes are not much more difficult.

### **Establishing a New Code**

Recall that your computer uses an 8-bit version of ASCII internally. Imagine taking the upper three bits and simply throwing them away. What's left are the five least significant bits of information. Baudot code is a 5-bit code, so we've matched the number of bits. Also, for the sake of this discussion, imagine that you have commanded your computer to run at 45.45 bauds, the equivalent of 60 wpm on a teletypewriter. (This can be difficult, if not impossible, on some machines. It is not a standard data rate in modern systems, but is easily implemented on others. Other methods can be used to overcome the problems encountered with some machines.)

We now have a computer system using 5-bit code at the proper speed. However, if you hook up such a system and try to decode teletypewriter transmissions, you'll have very limited success. You will indeed have information printed on your screen in-step with the received signal, but it won't be in any form you can understand.

### **Translation Tables**

One key element is missing. Even though you have changed the speed and are ignoring the three most significant bits of each character, your computer is still thinking in ASCII. Actually, no matter what you do, that will always be the case.

Just as diplomats rely on translators to help them do their job, you can create a translation table to translate the received Baudot code to ASCII. One is shown in *Figure 3-15*. Although the computer continues to think and operate in ASCII, the translator produces readable data on the screen or printer.

### **Programming Implications of Advanced Modes**

While the specific technique varies with other modes, the same idea can be applied to Morse code. AMTOR and packet radio use these techniques also, but additional processing must be done. Remember that AMTOR and packet are synchronous forms of communications. They also rely on a very sophisticated set of communications rules, called a *protocol*. The more complex the communications protocol, the more work your personal computer must perform. Particularly with the error-correcting, synchronous modes we've discussed, many computers have difficulty executing instructions fast enough to keep up with everything required to properly transmit and receive information.

Software packages are available for individual modes, but many programs, both commercial and public domain, combine several modes in the same package.

### **Smart Radio Modems**

Actually, in modern amateur equipment, the distinction between DCE and DTE can blur. Amateur transmissions require some additional processing before display, which can be done either in the personal computer as we've discussed, or in special circuitry placed in the interface or radio modem itself. From a hardware standpoint, it is less expensive to do the conversion through special software placed in the computer when it is being used as a DTE. This has been the popular method used by amateurs for a number of years. However, since microprocessors have become relatively inexpensive, many manufacturers have decided to build smart radio modems that convert everything to ASCII before sending it to the computer.

### **Combining Hardware and Software Into One Unit**

A very popular approach is to combine the hardware and software for multiple modes into a single unit that has its own processing power. The output from such a universal unit generally takes the form of an RS-232 connection. Connection to the computer is as simple as connecting a regular telephone modem. No special software is required. The same program you use for telephone computing will do nicely. It also has the advantage of not becoming obsolete if you change computers. As long as an RS-232 connection is available, the interface can still be used just as effectively. Even upgrades to the internal software in the unit are relatively straightforward. By swapping one or more erasable programmable read-only memories (EPROMs), additions and modifications can be made at minimal cost. A typical smart radio modem is shown in *Figure 3-16*.



**Figure 3-15. A look-up table like this one can be programmed into your computer to convert Baudot code to ASCII and back.**

In the Baudot code listing, the first column shows the character printed when the receiver is in the "Letters" mode and the third column shows the character printed when the receiver is in the "Figures" mode. Notice if the higher order three bits of the ASCII code are stripped off, the code is the same as the Baudot code directly opposite it.

Baudot Code						ASCII Code									
	5	4	3	2	1			8	7	6	5	4	3	2	1
E	0	0	0	0	1	3	A	0	1	0	0	0	0	0	1
*CR	0	0	0	1	0	CR	B	0	1	0	0	0	0	1	0
A	0	0	0	1	1	— (dash)	C	0	1	0	0	0	0	1	1
*SPACE	0	0	1	0	0	SPACE	D	0	1	0	0	0	1	0	0
S	0	0	1	0	1	'	E	0	1	0	0	0	1	0	1
I	0	0	1	1	0	8	F	0	1	0	0	0	1	1	0
U	0	0	1	1	1	7	G	0	1	0	0	0	1	1	1
*LF	0	1	0	0	0	LF	H	0	1	0	0	1	0	0	0
D	0	1	0	0	1	\$	I	0	1	0	0	1	0	0	1
R	0	1	0	1	0	4	J	0	1	0	0	1	0	1	0
J	0	1	0	1	1	(bell)	K	0	1	0	0	1	0	1	1
N	0	1	1	0	0	,	L	0	1	0	0	1	1	0	0
F	0	1	1	0	1	!	M	0	1	0	0	1	1	0	1
C	0	1	1	1	0	:	N	0	1	0	0	1	1	1	0
K	0	1	1	1	1	(	O	0	1	0	1	1	1	1	1
T	1	0	0	0	0	5	P	0	1	0	1	0	0	0	0
Z	1	0	0	0	1	"	Q	0	1	0	1	0	0	0	1
L	1	0	0	1	0	)	R	0	1	0	1	0	0	1	0
W	1	0	0	1	1	2	S	0	1	0	1	0	0	1	1
H	1	0	1	0	0	#	T	0	1	0	1	0	1	0	0
Y	1	0	1	0	1	6	U	0	1	0	1	0	1	0	1
P	1	0	1	1	0	0	V	0	1	0	1	0	1	1	0
Q	1	0	1	1	1	1	W	0	1	0	1	0	1	1	1
O	1	1	0	0	0	9	X	0	1	0	1	1	0	0	0
B	1	1	0	0	1	?	Y	0	1	0	1	1	0	0	1
G	1	1	0	1	0	&	Z	0	1	0	1	1	0	1	0
*F	1	1	0	1	1	FS									
M	1	1	1	0	0	.									
X	1	1	1	0	1	/									
V	1	1	1	1	0	;									
*LTRS	1	1	1	1	1	LTRS									

\*non-printing

CR = Carriage Return  
 LF = Line Feed  
 FS = Figures Shift  
 LTRS = Letters Shift

*Courtesy of QSKY Publishing*



# Packet Radio Communications

## THE SEARCH FOR ERROR-FREE DATA COMMUNICATIONS

The idea of an error-free data communications network goes back just about as far as communications itself. The earliest forms of written and spoken communications were subject to the introduction of errors. Over time, men and women have worked on ways to improve their communication skills and to eliminate errors. Yet, if you play the game called “gossip” where a story is passed from person to person and the beginning and ending versions are compared, the ending version differs greatly from the beginning version, partly because of errors that occur during the transfer of data. The electronic transfer of data is no exception. It also has the possibility of errors as the data is transmitted.

### Simple Error Correction

For a starting point, let us consider what telegraphers and teletypewriter operators have done for years to assure error-free transmissions. Messages are usually transmitted exactly as written without repeating any of the data. But to build confidence on the part of the sender and receiver that the message is accurate for such things as arrival dates, amounts of money, and other vitally important information, such information is often transmitted twice, as shown in *Figure 4-1*. Of course, when sections of a message are not received because of interference of some type, the receiving operator can manually request a repeat of the affected part. However, sometimes the receiving operator just takes an educated guess at the jumbled information and attempts to straighten it out. The result can be far from satisfactory.

### Modern Electronic Methods

In modern data transmissions, the simplest form of error-detection is the 1-bit parity check. We’ve already explained the parity bit and how it is used. It serves well for simpler types of transmission, but leaves a great deal to be desired as a form of error detection when the data transmission gets more complex. To help us understand the problems, let’s see what is required to design an error-free system.



**Figure 4-1. Critical data can be repeated to insure its accuracy. Notice how the critical information in this telegram is repeated.**

<b>MAILGRAM SERVICE CENTER</b> MIDDLETOWN, VA. 22645 21AM	<b>Western Union Mailgram</b> <small>UNITED STATES &amp; CANADA</small>
---	--

4-0062075294002 10/21/86 ICS IPMBNGZ CSP SFGC  
 1 MGM TDBN SPRINGFIELD IL 10-21 0951A EST

▶ JAMES W GRUBBS III  
 SPRINGFIELD IL

THIS IS A CONFIRMATION COPY OF THE FOLLOWING MESSAGE:

TDBN SPRINGFIELD IL 36/31 10-21 0951A EST  
 INT TF0642163602 REINHARD BIRCHEL CARE BEAM-VERLAG  
 BAHNHOFSTR 30 POSTFACH 1148, 3550  
 MARBURG/LAHN (WESTGERMANY)

THE TERMS OF YOUR LETTER DATED 8 OCT GENERAL ACCEPTABLE. PROCEED WITH  
 TRANSLATION. DETAILS FOLLOW VIA AIRMAIL. CHEERS.  
 JIM GRUBBS

COL TF0642163602 30 1148, 3550 8  
 0950 EST  
 MGMCOMP MGM

THIS IS THE CONFIRMATION LINE.  
 NOTE HOW NUMBERS HAVE BEEN  
 REPEATED HERE.

## DESIGNING AN ERROR-FREE SYSTEM

Working from the ground up, let's design a point-to-point data communications system and optimize it as best we can. We can use anything we've learned until now.

### Parallel or Serial?

To begin, let's decide whether our communications path will be parallel or serial. If cost were not a problem, we might choose to transfer information in parallel. Certainly this would give us the fastest speed and perhaps better and more reliable timing. Realistically, however, it is very expensive to transmit data in parallel over a distance of more than a few dozen feet. Therefore, being practical, we choose serial transmission.

## Asynchronous or Synchronous?

Will our data be sent using asynchronous or synchronous techniques? If asynchronous is chosen for its simplicity, a lot of time will be used to send start and stop bits, effectively slowing the data transfer. Some years back, engineers were often forced to live with the reduction in speed because the cost of synchronous equipment was prohibitive in many applications. However, with integrated circuit technology, synchronous transmissions are now cost-effective, so we'll use synchronous.

## Computer Interface

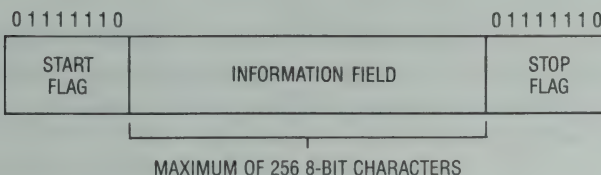
Our communications path must be easy to interface with computers because computers are used as much today for text generation and manipulation as they are for number crunching. Computers generally transfer information in groups of eight bits, or a multiple of eight bits, so let's design our path to deal effectively with 8-bit characters. This allows us to handle ASCII characters which are commonly used for text. Keep in mind that we might also like to send non-ASCII coded information, but for now, we'll concentrate on text transmission.

## What Speed?

We also need to choose the transmission speed. It would be nice to use a very high transfer rate of tens of thousands of data bits per second, but we must be realistic. Recall that the maximum speed of a data transmission is directly proportional to the bandwidth available on the communications path. The most common path is the telephone line, so let's choose it. A voice grade telephone line will generally not support a data rate above 600 bauds. Since 300 bauds is common, we'll use it.

With the decision to send serial, 8-bit data, usually encoded in ASCII form, using synchronous transmission methods at a speed of 300 bauds, we have established the basic rules for our path. Given these parameters, it is possible to actually begin transferring information between two points. Our data will be transmitted in blocks as shown in *Figure 4-2*. Each block will have a *start flag*, a *stop flag*, and up to 256 characters between the flags, each with eight bits.

**Figure 4-2.** Shown here is the basic form of synchronous transmission block upon which packet radio is built.



## THE ACTUAL TRANSMISSION

We'll use frequency shift keying (FSK) because it is efficient for transmitting over telephone lines. Recall that, when transmitting, a modem converts the digital signals from the computer to two tones before transmission. When receiving, the modem converts the tones into digital signals that the computer recognizes.

### Synchronous Format

A synchronous transmission begins with a start flag to alert the receiving station. Additionally, the unique coding in the start flag synchronizes the receiving station with the transmitting station. The process of extracting timing information from the start flag is called *clock recovery*.

Theoretically, an infinite number of data bits can follow a single start flag; however, over long transmissions with only one start flag, the sending and receiving stations can drift out of synchronization. This, of course, would result in errors in the received data. In the real world, transmission is usually limited to 256 characters of eight bits each. Some systems allow more, others less.

## BUFFERING

### Need for Buffering

If our path is to be used for on-line keyboard communications, much of the transmission time is going to be wasted waiting for the operator to press the next key. Because we have chosen to send the data in a synchronous fashion, we have no way to pause between characters while the operator looks for another key. During such periods, we must send a null character just to fill up the space. That can be as wasteful as using start and stop bits for each character.

### The Solution

To solve the problem, we can have the keyboard information stored in a special group of memory cells, called a *buffer*, until a group of letters have been typed. When the buffer is filled with the maximum number of characters allowed in the block, it is *framed* with a start flag and a stop flag, then sent on its way. We can arbitrarily set the number of stored characters to any number up to the maximum allowed by our system. The block in *Figure 4-2* allows 256 characters. If we want to send less than the maximum number of characters, we can define a *send character* to force transmission of data at any point. The RETURN or ENTER key on a computer is commonly used for this purpose in a synchronous communications system.

By buffering the information, time isn't wasted on the communications path. The waiting can be done at the computer terminal rather than on the communications path. A little later, we will see how the idle time on the communications path can be utilized by other computerists.

With buffering added, information can be exchanged efficiently between the transmitter and receiver. While it's an efficient system, there is nothing to ensure the integrity of the received data. To improve data integrity, it's necessary to add error detection and correction to our system. We'll start with error detection.



## ERROR DETECTION

Data engineers have devised a number of methods to spot errors in computer transmissions. Most of them rely on performing one or more mathematical calculations. One of the most popular methods involves the use of *cyclical redundancy check* (CRC) calculations. (In amateur packet systems, CRC is sometimes referred to as frame check sequence (FCS).)

### CRC

The theory behind CRC is somewhat complex. All you need to understand is that scientists and mathematicians have devised a mathematical formula that can be applied to any group of data bits to generate a unique number. Put another way, the results of the calculations for different data will almost always yield a unique binary number. How unique? You would have to send many millions of data bits before running the risk of duplicating the same CRC result.

Data to be sent is held in a buffer to allow time for the CRC calculation to be made before sending the data. Special integrated circuits handle the mathematics automatically. The CRC is appended to the end of the data. On the receiving end, the same type of circuit calculates the CRC for the received data and compares it to the CRC transmitted with the data. If the CRCs match, the receiving station can be almost certain no errors have occurred. If they don't match, corrective actions can be taken.

## ERROR CORRECTION

With the CRC calculation in place, our communications path has the ability to detect errors. Now we want to provide automatic error correction when an error is detected.

### ACK and NAK

Generally, the receiving station acknowledges properly received data by sending an *acknowledge* (ACK) signal to the originating station. If the data is not correctly received, the receiving station sends a *negative acknowledge* (NAK) signal to the originating station. When the originating station receives a NAK signal, it resends the information that was in error.

The receiving station allows only valid information to pass to the screen or printer. Once valid data is received, the receiving equipment reassembles the message in the proper order.

### Implied NAK

In systems that use an *implied NAK*, the receiving station does not actually transmit a NAK signal when invalid data is received, rather it simply doesn't send an ACK. The originating station uses a timer system that creates a period during which an ACK is expected for each transmission. If an ACK is not received, a NAK is implied and the appropriate data is automatically resent.

Why use an implied NAK system? In the case of a communications system where each block of data is individually addressed, an error may occur in the

address. The addressed station won't receive the data, so it won't send an ACK, and the block will be resent.

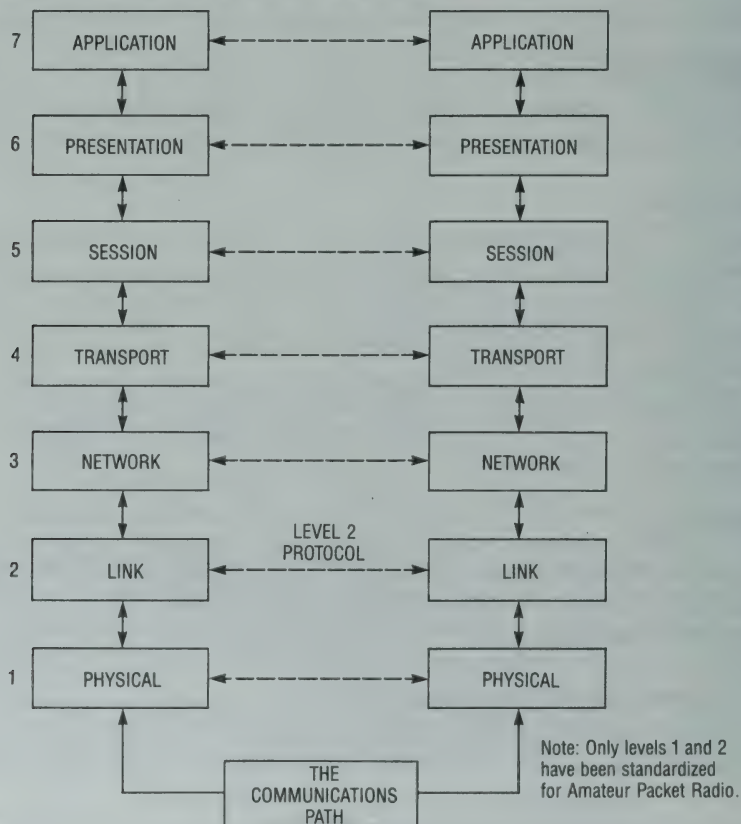
Congratulations! You have now mastered the basics of a serial, synchronous, error-detecting/correcting method of data transmission. What you have not done is create a complete packet transmission system. It takes a bit more to accomplish that.

## DEFINING A PACKET SYSTEM

### Communications Standards

Various standards for communications have been established over the years. As worldwide communications became commonplace, it was necessary to establish international standards. The seven levels of the Open Systems Interconnection Reference Model (OSI/RM) established by the International Standards Organization (ISO) are illustrated in *Figure 4-3*. They range from the physical level, which is for the physical equipment connections to implement the transmission method itself, up to the application level. Only the first two levels are presently defined by Amateur Radio operators for packet radio.

**Figure 4-3. The OSI/RM Networking model, usually called simply OSI, creates seven separate layers for data transmission protocols.**



The people pursuing the development of various communications systems have agreed to special sets of rules and procedures, called *protocols*, for communications. Not only are different protocols used for different kinds of communications, but also different protocols are used for essentially the same kind of communications. Both ends of a transmission link must use the same protocol for effective communications.

### **X.25 Protocol**

An international committee created the X.25 protocol a number of years ago. Today, it is commonly used in commercial telephone line data systems. It is not the only one, because others also are used in these systems. The X.25 protocol defines the interface between DTE and DCE for terminals operating in the packet mode on public data networks.

### **AX.25 Protocol**

Since we are most concerned with Amateur Radio packet techniques, we will focus our attention on the version of X.25 modified for Amateur Radio, AX.25<sup>SM</sup>. The A, of course, stands for Amateur. Other protocols are used, but AX.25 leads the way by a wide margin.

### **Other Protocols**

Other protocols that have been used for amateur packet radio include the Vancouver protocols, V1 and V2. These are somewhat different implementations of packet communications in the amateur world. In fact, the Vancouver version is the original one used by hams. The differences between Vancouver and AX.25 protocols are great enough to make the systems incompatible, but they are based on the same techniques.

### **Using Idle Time**

When a person is typing information as it is transmitted to a distant computer, long periods of time go unused while the operator searches for the next key, or pauses to look up information. While the main computer searches for the requested information, the transmission path goes unused during the time it takes for the computer to locate the particular record or data requested. If we can make use of this idle time on the communications path, everyone will benefit.

If we remove our carrier or tones from the path except during actual transmission, the same communications path can be shared with other operators. This would greatly increase the efficiency of a data network and ultimately reduce the per user cost of the system. However, before the communications path can be shared, it's necessary to establish a way to determine when a station can access the shared path.

### **Determining Access**

In a shared system, everything is fine as long as only one station transmits during a time period. However, if two or more stations try to transmit simultaneously, their signals interfere with each other and neither transmission is received correctly.



### ***Slotted Time Periods***

One method to prevent interference, or *collision* as it is sometimes called, is to assign a specific time period, or slot, during which only one station is permitted to transmit. For example, if four stations are sharing a path, each minute could be divided into four equal parts, and each station would be allowed to transmit only during its assigned slot. This method works, but at any given time, one or two stations may have a lot of traffic to send, while others have absolutely nothing to send. The result is a lot of wasted time that could be used by the station(s) with traffic.

### ***Polling***

A variation on the slotted assignment technique requires individual stations to be polled to see if they have anything to transmit. A station that consistently responds with no traffic to a polling inquiry is not polled as often. This results in some delay when the station finally has data to send, but the other, more active, stations benefit in the meantime.

### ***CSMA***

The amateur community has adopted a standard system to determine who has access to the communications channel at any given time. Since the presence or absence of a carrier determines if the channel is available, this system is called *carrier sense, multiple access* (CSMA).

Figure 4-4 illustrates a CSMA network. In the figure, station 1 is transmitting to station 3 and station 4 is transmitting to station 5. Now let's suppose that station 2 wants to transmit data to station 1. Station 2 checks to see if the channel is idle. Since the channel is in use, station 2 does not transmit, but continues to monitor the channel. When the channel is clear, station 2 begins transmitting.

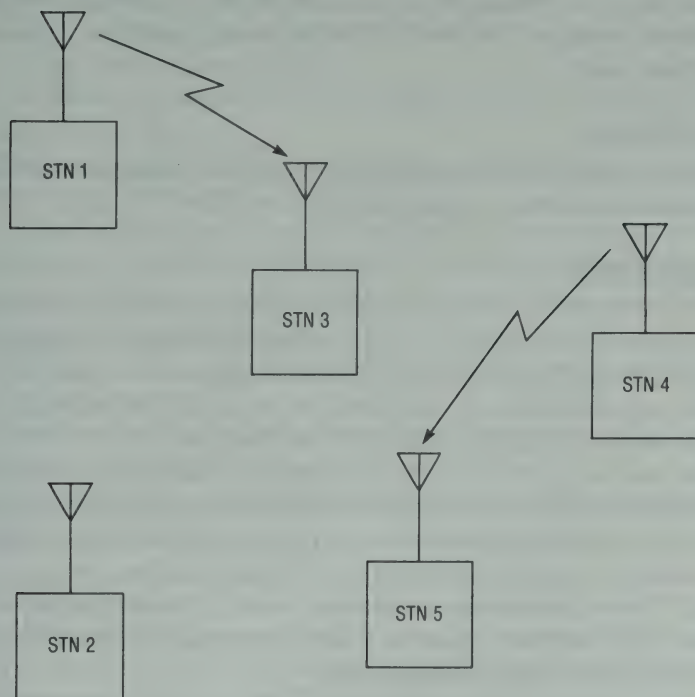
There still is a possibility for a problem. For example, suppose two stations have data to send, so both are waiting for the channel to clear. When it clears, both begin transmitting at the exact same time so they cannot detect each other. Of course, both transmissions are garbled. Fortunately, there is a way to resolve this situation. When the expected acknowledgment is not received, a timer in each station generates a short, but random, delay before trying the transmission again. The random delay helps ensure that the two stations will retry at different times so one can seize the channel and the other can detect its presence.

With several stations sharing the same path, it is mandatory that each transmission carry both the sender's and the receiver's identification, called the *address*. The AX.25 protocol provides for this requirement.

## **LAYING OUT THE PACKET**

By adding to the synchronous, error-detecting/correcting system we have defined, we can create a packet radio system. The first thing we need to do is reserve a portion of the information field for some special data. This information immediately follows the start flag and precedes the actual data. Both the sending and receiving stations are identified using standard amateur callsigns. Since the longest callsign consists of five letters and a single numeral, we need at least six character positions available.

**Figure 4-4.** In a CSMA system, stations can share a single channel but must monitor constantly to avoid colliding with other transmissions.



## SSID

The designers of AX.25 went one step farther and added another position called the secondary station identification (SSID). This is a number between decimal zero and fifteen that is appended to the end of each callsign. This additional identifier is needed because each amateur operator is issued only one callsign, but can conceivably operate many stations. For example, K9EI might run a bulletin board system and a digital repeater in addition to a regular terminal system. It would be confusing if all of them used the same callsign. By assigning a unique SSID to each one, confusion is avoided.

The terminal is usually SSID zero. Internally, it is identified as K9EI-0, but on the screen, callsigns with an SSID of zero are displayed without the SSID characters. The bulletin board system might be designated K9EI-1, while the digital repeater might carry the callsign K9EI-2. Additional identifiers through K9EI-15 are available, for a total of sixteen unique combinations.

PID

The term *packet* comes from the idea that information destined for the same location is bundled together into small packages before transmission. A *packet* consists of one or more frames, and a *frame* is a single collection of data bits. The frame number (zero through seven) is included along with information on the packet type being sent. There are also a few more bits, called the *protocol identification* (PID) bits, in the header part of the packet transmission that identify exactly what version of AX.25 is being used.

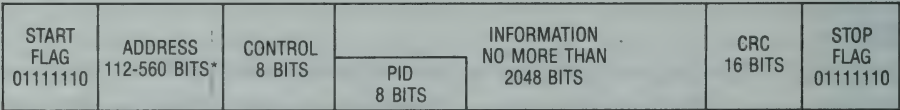
Types of Packets

Not all packets are the same in make up. They can be divided into two basic types, information and supervisory, as shown in *Figure 4-5*.

Information Packet

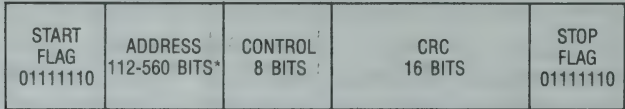
The information packet contains an information field, which may or may not contain PID bits, a control field, an error-correction field, an address field for sender and receiver, and the start and stop flags. When two stations are connected in error-correction mode, the frames are numbered so the packets can be tracked. It is also possible to transmit an information packet that is not error-checked. Such transmission, which can be equated to AMTOR Mode B, is usually used to send a short piece of information through the data network to any monitoring station. Since there is no connection between the stations, there is no way for the transmitting station to know if the information is properly received or not. This type of transmission can be used for a rough form of round table conversation where all the stations are receiving each other quite clearly and don't need the advantages of error checking. This type of packet is also used for beacon transmissions.

Figure 4-5. Single AX.25 information and supervisory frames in block form. Supervisory frames are shorter since they carry no information field.



\*Depends on the number of digipeaters used.

a. Information and Unnumbered Information (UI) Frames



\*Depends on the number of digipeaters used.

b. Supervisory and Unnumbered Frames



## **Supervisory Packet**

The supervisory packet contains the same fields as an information packet except there is no information field. The supervisory packet transmits no information from station to station, but helps control and supervise the path between the two connected stations. The frame type being sent is declared in the control field of each packet.

Common abbreviations for the various types of frames include:

SABM — The Set Asynchronous Balanced Mode is the connect command.

DISC — This is the disconnect request.

DM — The Disconnect Mode is used as a response to any frame other than a SABM while disconnected

UA — The Unnumbered Acknowledge is a response indicating an ACK for unnumbered frame commands.

FRMR — The Frame Reject is issued when a received frame passes the CRC check, but cannot be processed. This means a protocol error has occurred.

UI — The Unnumbered Information frame is used for transmission of information when no connection exists.

RR — The Receive Ready acknowledges reception of information frames and includes the frame number.

RNR — The Receive Not Ready indicates the station is temporarily busy. For example, the buffer might be full.

REJ — The Reject frame requests the retransmission of information frames that are received out of sequence.

## **OTHER PROTOCOLS**

Early forms of amateur packet protocol, such as Vancouver, actually did not use as much identification as we have talked about to this point. In fact, callsigns were not used. Each station was assigned a specific node number. At first only 64 combinations were available, but that number was later increased to 256. On the one hand, assigning a special numerical node identification makes handling packets somewhat easier. On the other hand, someone must control the assignment of node identifiers whereas callsigns are already unique and controlled.

If amateur implementation of packet protocol remained true to the standards used on telephone line systems, we would pretty well have a packet system defined at this point. However, hams have chosen to mix several levels of networking together, at least for the time being.

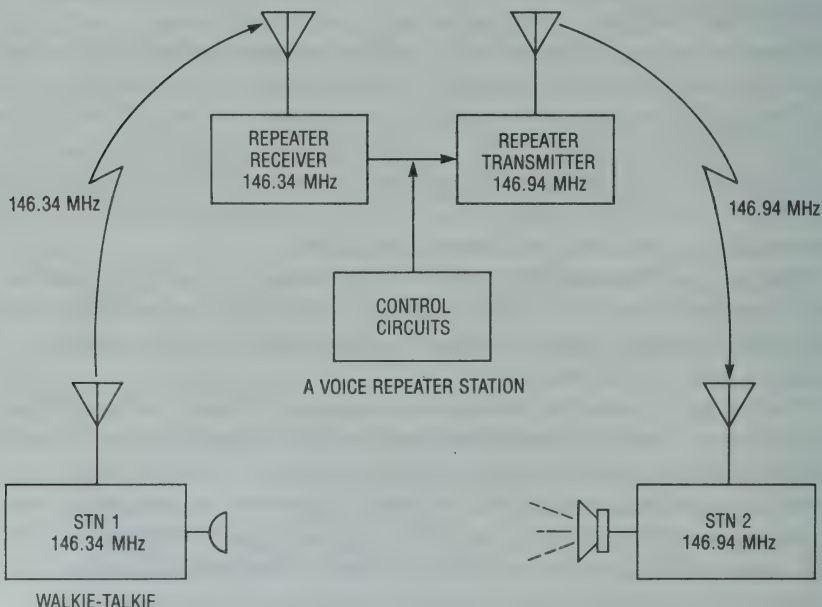
The standards created for the amateur community officially address only level two of the seven-level OSI model. Level two includes the basic format for individual messages and direct communications between two points. The third and higher levels address the rules for networking many stations together over a common system. At this writing, there is no agreed standard in the amateur community for the higher levels. Even without agreements on higher levels, an extension of level two allows for some rather impressive communications possibilities using repeaters.

## USING REPEATERS

### Voice Repeater Station

With voice operation such as that available to Novice class licensees on the 220 MHz band, a low power station, such as a hand-held FM walkie-talkie, does not have to be in direct range of the intended receiving station. Instead, the person with the walkie-talkie may transmit on the input frequency of a voice repeater that is within range. The antennas for repeater systems are usually placed in high locations to enhance their range. The weak signal from the walkie-talkie is received, amplified and retransmitted by the stronger, better located repeater transmitter on a separate frequency. That effectively boosts the signal strength of the very small radio to the strength of a much better equipped station. Direct communications with the walkie-talkie might be less than a mile, while repeater assisted communications approaches, and sometimes exceeds, twenty miles, depending on surrounding terrain and other considerations. *Figure 4-6* illustrates a voice repeater system. Here the walkie-talkie (or input) to repeater frequency is 146.34 MHz, and the repeater transmitter (or output) to destination receiver frequency is 146.94 MHz.

**Figure 4-6. FM voice transmissions can be relayed using a two frequency repeater system.**



## Packet Radio Repeating Via Voice Repeaters

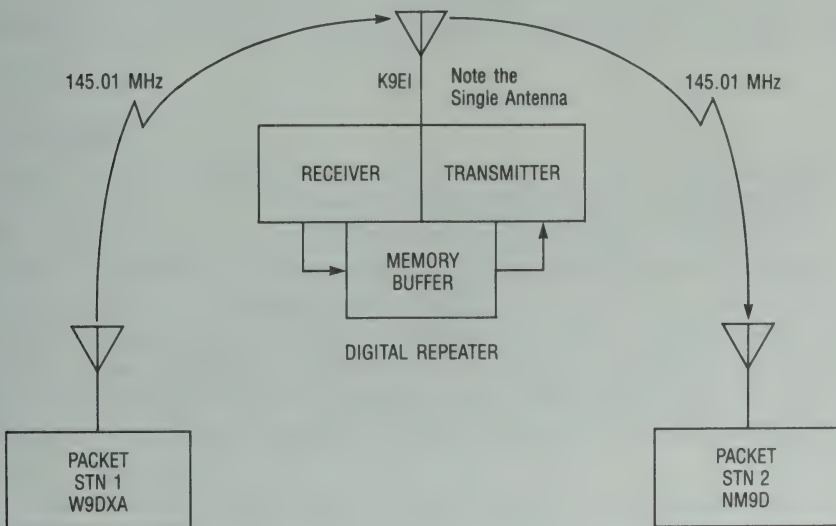
Packet radio can take advantage of voice repeaters without special equipment. Since the packet communications system has been designed to use the same bandwidth commonly available in voice systems, packet transmissions can be relayed by voice repeaters quite effectively.

Unfortunately, most voice repeaters are very busy with non-digital traffic and they can also be expensive to implement. Even though the transmitter and receiver operate on different frequencies, the frequencies are still close enough to cause interference without special precautions. Not only is a separate receiver and transmitter needed, but also either two antennas are required or a special filter called a *duplexer* must be used. Although a duplexer allows a single antenna to be shared, the duplexer is often more expensive than the rest of the system combined. If two antennas are used, they must be separated by dozens, sometimes hundreds, of feet.

## Digipeaters

Every amateur packet station (not a voice station) has the ability to serve as a digital repeater or *digipeater*. If W9DXA wishes to send a message to NM9D but cannot reach that station directly, W9DXA may relay or repeat through one or more interim stations. The originator, in this case W9DXA, specifies that his messages are to be sent to NM9D using one or more stations in between.

If K9EI is the station in the middle, as shown in *Figure 4-7*, the communications occurs in this fashion: The data from W9DXA is received at K9EI as usual. The information is not addressed to K9EI, but K9EI's equipment recognizes the information as data that is to be relayed. The received information is stored in a buffer. Once



**Figure 4-7. Packet radio uses a single channel store-and-forward digital repeater concept.**



the transmission is completely received, K9EI retransmits the exact same information with NM9D specified as the intended recipient. Since the transmission does not take place until after W9DXA finishes sending, only one channel is needed. K9EI's transceiver can be used for both the receive and transmit function and only one antenna is required. A slight delay is introduced since the data must be buffered before retransmission. This system is known as a *store and forward* packet repeater. K9EI, as any other digipeater, can turn off the digipeating feature of his packet station if he doesn't want others to be able to relay through his station.

Within the AX.25 protocol, provision is made for specifying up to eight interim repeater stations between the sending and receiving stations. That can significantly increase the range of a low power station. The biggest drawback is that when a station is operating in digipeater mode, no error-checking is done on the received data. Only the final station in the chain can recognize bad data. Chapter 7 discusses some possible solutions to this and other problems.

## SUMMARY

You now have a beginner's overview of packet radio, but all the theory in the world means nothing if you can't relate it to the world around you. Our ultimate goal is to connect our home computer to other hobbyists using the best data transmission methods available at the time. The Amateur Radio transmission, of course, is a very viable link. In the next chapter, we will take some time to explore the required hardware and software, and learn how to hook up a basic radio data communications station.

# Terminal Node Controller

## WHAT IS A TERMINAL NODE CONTROLLER?

A *terminal node controller* (TNC) is essentially a very smart modem especially designed for packet radio. It can make using a personal computer for packet radio much easier. Before we get into the details of its operation, let's find out why we need one and the basics of what it does. To do that, it will be helpful if we first see how a personal computer communicates over the telephone lines with a time sharing service.

## CONNECTING TO A TIME-SHARING SERVICE

When you want to connect to one of the major time-sharing information services like CompuServe® or The Source<sup>SM</sup>, you set up your computer essentially the same way as when you communicate with a hobbyist across town, then you dial a local telephone number. Once the connection is made, your computer begins communicating as usual, using standard serial, asynchronous signals at a relatively low speed, typically 300 or 1200 bauds. On the other end, however, something quite different happens.

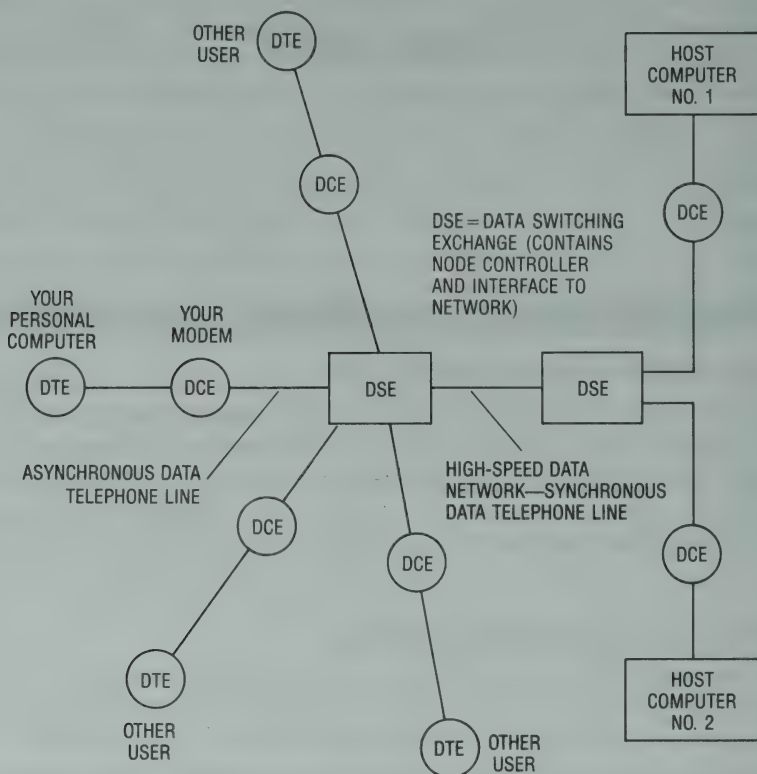
### The Local Node

The local number you dial connects your computer to a *local node* of the nationwide network. A *node* is simply a place where information from different locations comes together. The local node has a multi-port device called a *node controller*. Your computer is connected to one port, while other users in your area are connected to other ports. *Figure 5-1* illustrates this concept.

The node controller is actually a specialized computer dedicated to converting the asynchronous signal you send to the local node to the high-speed synchronous signal used on the network. It has full responsibility for receiving your data, putting it into packets containing the proper addressing information, and forwarding it through the network.

The other side of the local node is typically connected to a dedicated network of high-speed data circuits. They usually operate at speeds of tens-of-thousands of bauds, are synchronous in nature, and use packet transmission techniques. The

**Figure 5-1. Here is how you connect your computer into a time sharing information service.**



information you receive from CompuServe, for example, is broken down into information packets and placed on the line with other information packets destined for the same local node. This allows hundreds, and sometimes thousands, of users to share the same network.

### Watching the Packets Come In

You may be able to see a graphic example of packet at work by just logging onto your favorite service. When everything is working well, the delays introduced by packet technology are not noticeable. Everything is happening at such a speed that the delay is not discernible. However, if you frequently use popular services during peak hours at night and on weekends, you may have noticed some strange happenings, particularly if you use a 1200 or 2400 bauds connection. While displaying on your screen a file from the distant service, you may see a large number of characters appear almost at once, followed by a pause, then another group of characters, another pause and so on. You are seeing the packets as they come in! At 300 bauds, it may take longer to receive and display the data than the length of any delay. In that case, you won't notice this effect.



## Possible Errors

One of the things you may not be aware of is that for most of its trip, both your transmitted and received data is error-corrected! The weak link is the connection from your computer to the node controller. Any errors introduced on this path are not detected unless other means are taken to find them. That's why even on an error-free network like CompuServe, it is still necessary to use a communications protocol which has error checking, such as XMODEM™ or CompuServe B™, when sending and receiving programs or other critical files.

## TERMINAL NODE CONTROLLERS

While amateur radio packet radio networks have not yet grown to the complexity and speed of commercial networks, the conversion task between asynchronous and synchronous error-correcting transmissions is still quite formidable. As a result, most amateurs use a terminal node controller. The operation is similar to the node controller on a commercial network. The addition of the word *terminal* indicates that the hardware is connected directly to a terminal. You can also think of a TNC as a smart modem, one that not only performs basic sending and receiving functions, but also detects and corrects errors and manipulates the data internally.

## Using a Personal Computer as a TNC

The process of converting from low-speed, asynchronous transmission to high speed, synchronous, error-correcting networks is a very demanding job. Many of the necessary functions can be handled by a personal computer, but only with great difficulty, largely due to the very critical timing considerations involved.

For amateur packet radio, the tasks involved in sending and receiving the AX.25 protocol are very complex and a large amount of programming code must be implemented. The coding itself, while beyond the capabilities of most amateur programmers, is not so complex that it cannot be fitted into the typical personal computer; however, it pushes the personal computer to its limits. In Chapter 8, we will spend some time exploring how this can be done.

Trying to execute the complex code quickly enough to keep up with the data flow on the communications channel is the problem. While some personal computers are now designed to run at clock speeds between eight and 20 MHz, and internally handle 16 or 32 bits of information at one time rather than only eight, many hobbyists still have 8-bit machines running at clock speeds between 1 and 5 MHz.

The easy way out of this situation is to use the personal computer only as a smart terminal and use a stand-alone TNC to handle the calculations and assembly required for packet transmission and reception.

## Stand-Alone TNC

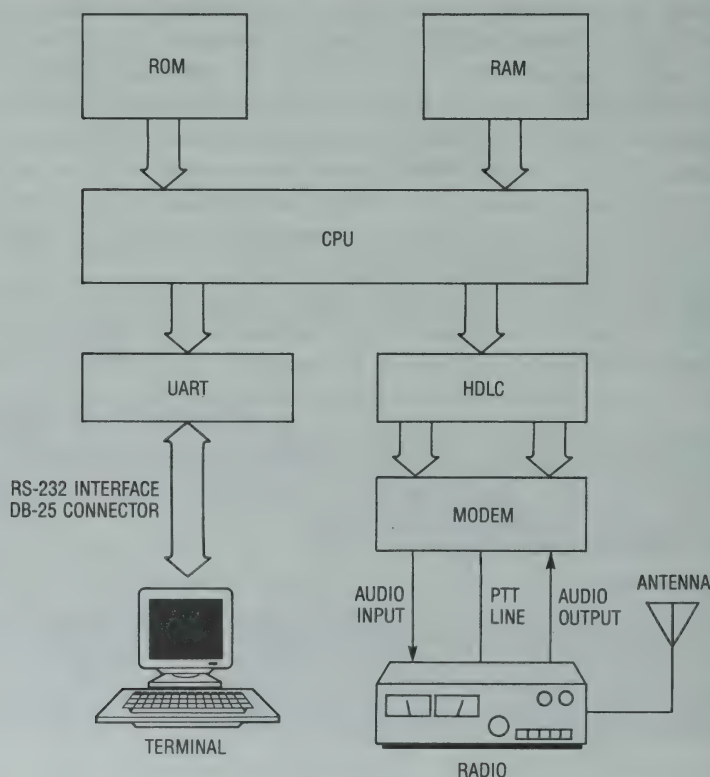
Early developers in the amateur community decided to direct their main efforts to designing a stand-alone TNC. They felt that it was the most economical way to go in the long run. Since current TNC prices are comparable in cost to those for a much less sophisticated standard telephone modem, it seems their vision was a good one.

Figure 5-2 shows a block diagram of a stand-alone TNC. We can see that the TNC contains a CPU to process the program instructions, read-only memory (ROM) to store fixed program instructions, random access memory (RAM) to store variable program instructions and data, a UART to perform parallel/serial conversion of data for the terminal, a HDLC to format the data for synchronous transmission, and a modem to couple the data to the radio link.

### HDLC, PAD or FAD

In addition to microprocessor chips used for the CPU (these chips are the same as the ones used for general purpose applications), integrated circuits designed especially for commercial packet equipment make the job of implementing amateur packet protocol in a TNC much easier. These chips, such as High-level Data Link Control (HDLC), packet assembler/disassembler (PAD), and frame assembler/disassembler (FAD), are named for the functions they perform. Thus, a large part of packet processing can take place in a single component. If you want to use your personal computer for the TNC task, it is possible to add these components via a plug-in card designed for the task. However, as stated previously, it is not common for hobbyists to operate packet with such a system because of the software and firmware detail required to get the system operating.

**Figure 5-2. A block diagram of the major components of a TNC.**



## Connectors

Many TNCs provide a DB-25 connector with pin connections in accordance with the RS-232C standard for connecting the TNC to the terminal. That's not an accident. Virtually all TNCs are designed to communicate with a terminal in exactly the same way a telephone modem does. Recall that the input and output at the RS-232 connector is an asynchronous serial signal. The terminal's communications software permits the speed to be adjusted from about 100 bauds up to 19,200 bauds. All the information transfers between the terminal and the TNC go through this connector.

On the modem side of the TNC, a variety of connectors provide the physical connections to the radio for audio input, audio output, and the push-to-talk (PTT) function. Some units use DIN type plugs, some use nine-pin D-subminiature connectors, and some seem to use whatever was handy.

## TNC Modem

Much of the original packet activity occurred on VHF and UHF radio circuits where 1200 bauds was chosen as the operating speed. Experimenters found a large number of specialized 1200 bauds modems available on the surplus market at an attractive price and decided to use them as the standard for Amateur packet radio. Thus, the TNC modem circuit is quite similar to a telephone modem circuit.

## Bell 103 and 212 Standards

Recall that 300 bauds telephone communications generally is in accordance with the Bell 103 standard. It uses frequency shift keying and determines the tones (shown in *Figure 3-5*) and other transmission characteristics. If 1200 bauds transmission is desired, the Bell 212 standard is used. It uses phase shift keying to attain the higher data rate. Both are full-duplex systems.

## Bell 202 Standard

The Bell 202 standard is the one that has really caught on with Amateurs. It is an earlier implementation of simplex or half-duplex using 1200 bauds FSK transmission. The tone frequencies are different from those used with the other standards (M-2200Hz, S-1200Hz). There is only one set of tones since transmission occurs in only one direction at a time.

Today, it is fairly easy to build a modem for the Bell 202 standard using just a chip or two. There is no reason the tone frequencies could not be changed, but tradition has continued and the Bell 202 standard has stuck for amateur packet activities.

## Asynchronous to Synchronous

While the output from a telephone modem remains asynchronous and usually remains the same speed as the signal coming from the computer, something quite different happens in a TNC. When transmitting or sending, the asynchronous data stream from your computer is converted into a special synchronous form by the TNC. When receiving, data is converted from synchronous to asynchronous.



## TNC Functions

Let's think about what must take place inside a TNC. When transmitting data, all of the terminal signals must be buffered until we either force transmission with a send character or the packet size reaches the maximum allowed. Remember that the buffering serves two purposes. First, it allows more efficient use of the radio communications path. Second, it allows a CRC (cyclic redundancy check) value to be calculated to assure error-free transmission.

In a fully implemented packet system, the information we want to send must be integrated with special handling instructions. These include the origination and destination addresses or callsigns and the other information we covered in Chapter 4. Each and every packet must have this information added for the system to operate properly. As you can see, it's beginning to take some work to transmit even a single packet of information.

Additionally, a packet system has to keep track of whether or not an acknowledgment (ACK) has been received. More than one packet can be outstanding at any given time, so the system must have a way to keep track of packets. For example, it is possible for packet number five to have been transmitted before an acknowledgment is received for packet number three.

## TNC Processing

The calculating of the CRC and the packaging of the information along with the necessary header information is accomplished within the TNC. The microprocessor functions in much the same way as the microprocessor in a microcomputer. It has control over the entire operation. The control program is contained in one or more EPROMs. One or more RAM chips are used to buffer information coming from and going to the personal computer terminal and to provide storage of some user options. Communication chips provide the necessary interfacing for both the computer side and radio side of the modem. The HDLC chip and other special circuits designed for packet protocol assist the processor in the complex task of assembling packets for transmission and disassembling received packets. *Figure 5-3* shows the inside of a TNC.

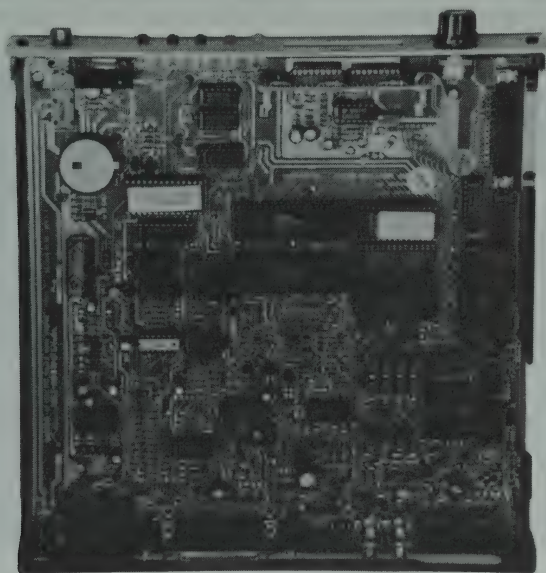
Circuitry is included to extract the clock signal from received packets so that proper synchronization occurs. Additionally, a multitude of timer circuits constantly keep track of how long it has been since a packet was transmitted, how long the transmitter has been on the air, the time since the last transmission was monitored on the channel, and more. That's why it's difficult to accomplish all of this with software in a personal computer and use it as the DTE as well!

## CHOOSING A TNC

The selection of commercially available TNCs has grown exponentially over the last few years. To help you select the proper hardware, let's take an overview of available equipment.

While a large variety of TNCs are available, most of them fall into one of several categories, making the choice somewhat easier.

**Figure 5-3. An inside view of the actual layout of a modern TNC.**



*Courtesy of MFJ Enterprises, Inc.*

## **Vancouver TNC**

In the earliest days of packet radio, each TNC was built by hand with very little standardization. The Vancouver group began to make it easier by producing a circuit board for a TNC. You still had to find all the parts, a Bell 202 modem, and have the software burned into a memory chip.

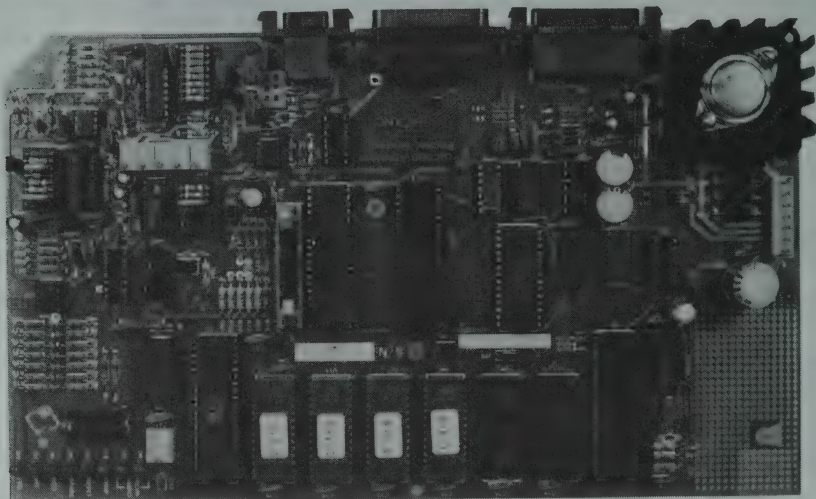
## **TAPR TNC 1**

The Tucson Amateur Packet Radio (TAPR) organization set a goal of designing a low-cost, easy-to-duplicate, self-contained TNC. They started by modifying Vancouver boards, but by the time the project was completed, the TAPR TNC 1 was a completely new design. TAPR sold a complete kit comprised of a bare circuit board and all the parts on a not-for-profit price of around \$300 when it was introduced. They wanted to make the technology available to the amateur community and to prove to equipment manufacturers that a packet TNC was a viable product. A complete board is shown in *Figure 5-4*.

## **Commercial TNC 1**

While the amateur community welcomed the introduction of the TAPR TNC 1, the commercial manufacturers approached packet radio very cautiously. AEA, Inc. was the first one to be licensed to produce an assembled version of the TAPR TNC. The initial cost was well over \$500! Others, including Heathkit also obtained a license. As a result, you can find on the used market today original TAPR units built by experimenters and commercial units built by licensed manufacturers. The TNC 1 can operate using either Vancouver or AX.25 packet protocol. A true standard still did

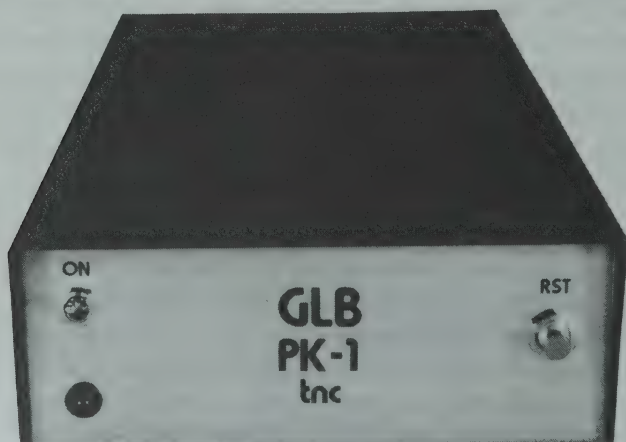
**Figure 5-4.** Early TNCs were constructed by hand usually from circuit boards developed by TAPR.



*Courtesy of Tucson Amateur Packet Radio Corporation*

not exist when the TAPR TNC 1 was introduced. Other manufacturers joined the packet revolution, but decided to design their own TNC hardware. Kantronics and GLB Electronics are two such companies. The Kantronics unit included a command structure and operation similar to the TAPR unit. The GLB product utilized a unique command scheme, but sold for significantly less. *Figure 5-5* shows one of the GLB products. The Amateur Radio community was fast becoming hooked on the idea of packet radio, but price tags in the \$300-500 range retarded the growth.

**Figure 5-5.** GLB Electronics opted to design their own circuits.



*Courtesy of GLB Electronics, Inc.*



## TAPR TNC 2

The TAPR group was still hard at work. Technology and collective experience had grown by quantum leaps since they first began the TNC 1 work. Now, they wanted to make a compact unit with improvements that could be manufactured and sold for less than \$200. The TNC 2 was born, and its birth was heralded throughout the amateur community. The design was solid and easily reproducible, resulting in a number of licenses being granted to produce similar units. The command set had been expanded and the hardware improved. With AX.25 now fairly standard around the world, the Vancouver protocol was dropped from the software support. Prices began at around \$200. After an initial run of TNC 2 kits, TAPR got out of the hardware business, preferring to concentrate volunteer resources on other packet developments.

## Commercial TNC 2

With the introduction of a licensed TAPR TNC 2 by MFJ Enterprises, shown in *Figure 5-6*, the price tumbled to \$129.95! At this writing, the TNC 2 units dominate the market place at prices ranging from just under \$100 to more than \$200. GLB, Pac-Comm™ Packet Radio Systems, and other manufacturers also offer licensed TAPR TNC 2 units. AEA offered the PK-80 for a period of time, but discontinued that unit in favor of another approach. Both Kantronics and AEA now offer products that support all of the features of a TNC 2, but utilize proprietary software.

## The Universal Terminal Unit

A relatively new breed of modem has emerged that may eclipse the popularity of all other models in the long run. The concept began a few years ago with the introduction by Kantronics of an Universal Terminal Unit™ (UTU™). At the time, the Kantronics UTU did not include packet capabilities, but did include all other amateur data modes from Morse, through Baudot and ASCII, to AMTOR. At the time of its introduction, most manufacturers, including Kantronics, were selling software or software/hardware combinations that could be used with only one brand and model of computer. The UTU pioneered a different approach.

**Figure 5-6. The MFJ-1270 TNC is one of the lowest cost and most popular TNC 2 clones.**

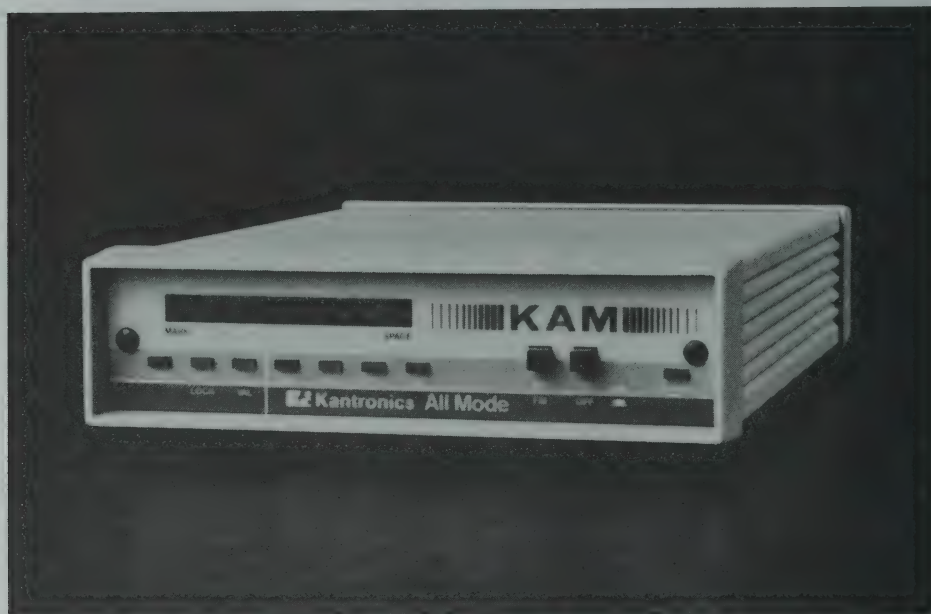


*Courtesy of MFJ Enterprises, Inc.*

Communication between a UTU and a personal computer is accomplished through a RS-232 connection, just as it is with packet TNCs. You need only standard communications software. As long as the computer can communicate in accordance with RS-232, the UTU can be used in any system. That's an obvious advantage if you think you may change computer systems in the future and don't wish to change your amateur radio modem. All that's required is a standard communications program for your new computer.

Kantronics now offers the Kantronics All Mode (KAM)<sup>TM</sup> unit, as shown in *Figure 5-7*, which has all the features of the earlier UTU and includes full packet capabilities. The AEA PK-232<sup>TM</sup> unit is similar in approach, but includes limited reception of facsimile transmissions in addition to the variety of data modes we have discussed. Incidentally, even owners of the older Kantronics UTU can have limited packet operation by simply installing a newer PROM.

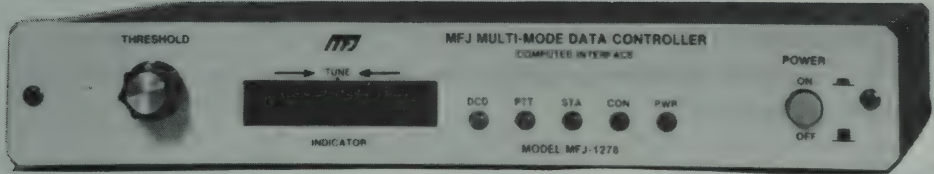
**Figure 5-7.** The Kantronics KAM unit is a state-of-the-art all-mode radio modem.



*Courtesy of Kantronics*

MFJ also offers a multimode unit. Its MFJ-1278 Data Controller shown in *Figure 5-8* offers operation on seven modes — Packet, ASCII, RTTY, CW, WEFAX, SSTV and Memory Keyer. It has HF/VHF/CW modems, software selectable dual radio ports, and precision tuning indicator. It operates using TAPR hardware and software.

**Figure 5-8. Seven modes of operation are provided by the MFJ-1278 Data Controller.**



*Courtesy of MFJ Enterprises, Inc.*

## Specialized Units

There are some additional variations on the TNC that we will look at in upcoming chapters. One unit sold by AEA for the Commodore 64 and 128 is a cross between a stand-alone universal unit and a machine specific unit, with the software resident in the personal computer. There are dual-port TNCs and now Network Node Controllers (NNCs). AEA also has recently introduced the first true packet radio — a transceiver specifically designed for high-speed data transmission and reception.

## Current Choices

In summary, the hobbyist currently has basically these choices for a TNC:

- A TNC 2 unit built by a licensed manufacturer. Price and proven reliability are the reasons for choosing these units. For the computer hobbyist interested only in packet operation, TNC 2 units offer an exceptional value in today's marketplace.
- One of the units using proprietary hardware and software. Initially, the amateur community was somewhat reluctant to invest in a unit supported only by a single manufacturer. However, the companies have proven that they are responsive to changing conditions and are having little difficulty in attracting buyers.
- A universal terminal unit. The combination of a universal computer connection using an RS-232 port and the relatively easy programmability of an all-mode unit makes a UTU very attractive for anyone wishing to engage in a wide variety of data transmission and reception modes.
- A specialized unit if the hobbyist's needs dictate.
- A used TNC. Most older TNCs are still compatible with today's equipment. Find out which version of software is included in the unit you are buying and check on the availability of upgrades direct from the manufacturer. TAPR intended to release an updated version of software for the TNC 1 that would fully implement the features available in the TNC 2. Because a number of problems developed during the project, it has not been completed. But all is not lost for two reasons.



First, the TNC 1 can still be used quite effectively in communications with TNC 2 type units, though there have been reports of incompatibility with some versions of some proprietary software. Second, Ron Raikes, WA8DED, has created a replacement software program available for use on a non-profit basis that implements many of the desirable features of the TNC 2 code on a TNC 1.

## GETTING CONNECTED

Let's now turn to the details of actually making physical connections and establishing software interfaces.

### The DTE

The DTE, or computer side of the connection, is just about as simple as it can be. If your computer has an RS-232 connection, particularly if it is terminated in a DB-25 connector, most of your work is done already. To begin, you will need a minimum of three wires: transmitted data, received data and signal ground. Refer to *Figure 2-15* for the location of these connections on a DB-25 connector.

While using the DB-25 connection from an RS-232 port is the easiest and most commonly accepted way of connecting a TNC to a computer, there are alternatives for some machines. In the case of Commodore computers, you can purchase a plug-in RS-232 adapter from several sources. A number of TNCs include special instructions for connection to the Commodore machines without using a special interface. Usually it is necessary to change the position of a switch or jumper inside the TNC to accomplish this. You'll then wire a special cable with a DB-25 on one end and a 24-pin user port connector on the other end to match the connections on a Commodore computer. At least one manufacturer sells a special cable completely wired for the Commodore. Some amateurs have successfully written software for other machines that allows the data to be sent and received through the joystick connection or other ports. We can't possibly cover all the methods used, though you may find some helpful hints in back issues of amateur magazines that regularly devote their pages to packet radio activities. In the long run, a true RS-232 connection is the desired way to connect your TNC.

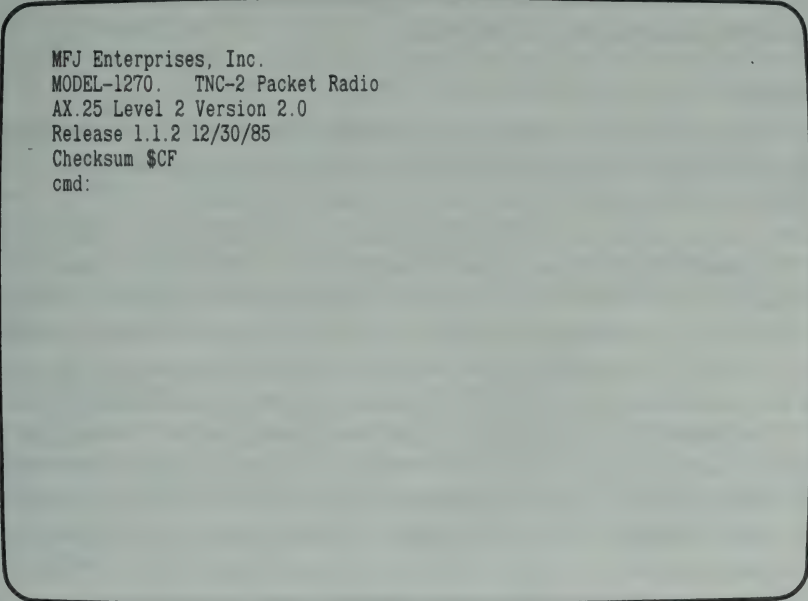
### TNC Software

You will also need to load some type of terminal emulation software into your computer just as you would to use a standard telephone modem. You can use the same software for packet radio as for telephone line communications. You do not need a special communications program for your computer to operate with packet radio! That is perhaps one of the most frequent misunderstandings people have about packet radio.

## TNC OPERATION

A terminal node controller has several modes of operation. When you first power it up, it will give you a sign-on message similar to the one shown in *Figure 5-9*. It usually indicates the manufacturer and the version of the internal software contained

**Figure 5-9. When you turn on your TNC, a sign-on message similar to this one should appear on the screen of your computer.**



```
MFJ Enterprises, Inc.  
MODEL-1270.   TNC-2 Packet Radio  
AX.25 Level 2 Version 2.0  
Release 1.1.2 12/30/85  
Checksum $CF  
cmd:
```

*Courtesy of MFJ Enterprises, Inc.*

in its PROMs. If everything is properly set up, you'll see a **CMD:** prompt on your computer screen (can be upper or lower case). In this mode, you are communicating directly with the CPU inside the TNC. This is the way you send instructions to the TNC itself.

From this prompt, you can initiate a connection to another station, check or change the many parameters of your TNC, switch modes, and much more.

## No Prompt Debugging

What do you do if the **CMD:** prompt doesn't appear? There are a number of possibilities. If you see something on the screen when powering up the TNC but it isn't readable, you probably have a mismatch of data rates between your computer and the TNC. Alternately, you may have the speed correct, but have the number of data bits, the type of parity, or the number of stop bits set wrong. This can result in garbage, or even nothing, appearing on your screen, so it's a good place to start.

You can adjust your computer's parameters through the communications software or adjust the TNC's parameters to bring them into agreement. The instruction manual for the TNC usually indicates the preferred parameters and how to set them. The speed on most TAPR type TNCs is adjusted by setting one or more DIP switches on the back of the unit. Remember, you are adjusting only the speed between your computer and the TNC itself. This has absolutely nothing to do with the baud rate used on the radio channel!

## Automatic Features

Some units utilize an autobaud feature. You connect your computer in the same fashion and power on the TNC. You wait until you see a special message print clearly on the screen and then press the \* key. The software inside the TNC is automatically locked into the proper speed.

## Commands

Setting a TNC's operational mode is not much different from using a smart modem. If you have a Hayes compatible telephone modem, you have similar choices of operational modes, though they may not be as readily apparent.

When you use a Hayes compatible modem, it powers up ready to accept certain special commands beginning with the capital letters AT. There is no prompt as such, you just have to know the correct combination of letters to use. Perhaps the most typical command is something like ATD5559988, which means dial the telephone number 555-9988. The circuitry in the modem takes over, automatically dials the number for you, and shows a CONNECT message once the connection is established. The modem then switches into a transparent mode before allowing you to proceed with communications. If it didn't do this, then anything you typed beginning with AT would be interpreted as a command to the modem. Of course, that simply wouldn't work. Still, there has to be a way to manually abort, so the Hayes command set recognizes the symbol +++ as a return-to-command mode. All three + signs must be sent within a short time period or they are not properly recognized.

Packet TNCs use a similar concept, although you start with a **CMD:** prompt on the screen. Once you execute a command, the TNC goes into the appropriate mode of operation. In most cases, pressing **Control-C** one time returns the **CMD:** prompt. When the TNC has truly been placed in transparent mode, it responds in a manner similar to the Hayes system. In the TNC case, three Control-C characters (others can be designated) must be sensed in a specified time.

## Connecting the Radio

Before the TNC can decode packet transmissions, it must be connected to your radio transceiver or transmitter/receiver combination. For this discussion, we assume that you want to operate packet using an FM transceiver on one of the popular VHF or UHF frequency bands. The specifics for HF operation are covered in the next chapter.

### VHF-UHF Operation

To begin, make sure that you have the receive audio connection from the TNC to your radio hooked up. The easiest way to do that is to connect to the speaker output on the radio or clip across the speaker leads of an external speaker. This is not the optimum way to do it, but it is the way most of us started, and the way many of us have operated for years. For now, leave the TNC transmit leads to the radio disconnected.



Perhaps the first thing you should do at the **CMD:** prompt is enter your callsign. Simply type **MYCALL KA9XYZ**. Your TNC will reply with a message like **MYCALL WAS NOCALL**.

With most new TNCs, your parameter choices are retained even when power is lost. TNC 2 type units, and most others manufactured recently, include a battery backup so that, even during a power loss, parameters retain the last value you entered. Some units like the TNC 1 used a device called a nonvolatile random access memory (NOVRAM). These chips allowed the user to place new values in the memory and then make them permanent through software commands. The chips were very expensive. If you have such a device, you will have to issue a **PERM** command to keep from losing your installed parameters.

Even so, not everything is backed up. For example, special beacon and connect texts are generally lost when power is disconnected from the TNC. You'll have to re-enter them.

## Receiving Packets

Right now we want to see if the TNC is receiving packets. If there is regular activity in your area, you might do well to just try reading the mail for a while. You must ensure that the **MONITOR** function is properly set. You want to set the TNC so the maximum number of packets will be displayed. Examples of monitored packets are shown in *Figure 5-10*.

**Figure 5-10. With the MONITOR function enabled, you can read the mail on local packet transmissions.**

```
cmd: mon on

KØHØA>WA5QZI
I do not know what the answer is. I think we need
to keep msg size
KØHØA>WA5QZI
down in the interest of speed and delivery.
NJ5N>NICWP <C>
KØHØA>WD5B <DM>
WA5QZI>KØHØA:
WA5QZI>
WA5QZI>ALAMO:
*Alamo Gateway - BBS connects only*
QTC: SYSOPS WA5QZI WØRLI KD5SL W5SMM KF5QB
KØHØA>WD5B:
SP WD5B < KØHØA
W2JUP-4>HFMAIL:
Long Island HF/VHF Mailswitch on line
KD5SL>WAØCQG:
will. We are getting ready to go out and do some
Christmas shopping etc.
```

All packets do not contain text or data. If you hear packets on the channel, but nothing is printing on your screen, it doesn't necessarily mean you are having TNC problems. You also have to look in the right place. On 2 meters, your best bet is likely to be 145.01 MHz, although activity takes place on other frequencies in some parts of the country.

The instruction book that comes with your TNC is your best bet for full information about the various **MONITOR** commands, but virtually all of them begin with the word **MONITOR**, the letter **M**, or the abbreviation **MON**. Some older TNCs don't make it very easy to monitor all packets. Most of the new units allow you to set the level of display you desire.

### **DCD**

If all is in order so far and you still are not seeing information displayed on the screen, several more items should be checked. Look at the data carrier detect (DCD) lamp on your TNC. It should light brightly when a packet signal is present. If it doesn't, suspect an open audio circuit or adjust the volume control upward until it stays lit when packets are received. In some installations it is also possible to have the volume set too high. Try adjusting the volume to different levels. We'll talk about the best way to optimize the receiver connection in a moment.

If things still are not going well, the problem may not be at your end. It is possible that the transmitting station may be off-frequency or deviating either too much or too little.

## **Possible DTE Problems**

Still other problems may be keeping you from communicating properly with the TNC. Remember in our discussion of RS-232 signals that we talked about handshaking as a method to ensure that data is not lost between the DTE and the DCE.

Either of two pairs of lines can be used for handshaking, or hardware flow control. The request to send (RTS) and clear to send (CTS) signals are one pair, and the data set ready (DSR) and data terminal ready (DTR) signals are the other pair. Some terminal programs check these signals and demand that they be in the proper state before allowing the terminal to communicate with a modem. Other programs do not implement these checks. If you are having problems along these lines, you'll either need to make the additional connections in your RS-232 cable, or connect a jumper between the proper pins.

While on the subject of flow control, let's take a quick look at XON/XOFF control. Typically, a **Control-Q** character is the signal from one piece of equipment to the other to begin or resume transmission. A **Control-S** character is the signal to stop transmission. Since these control characters are generated by the software and sent as regular ASCII data, they are referred to as software flow control.

It's a pretty good bet that any problems you are having up to this point involve either incorrect setting of communications parameters between your computer and the TNC, an open circuit, or a flow-control problem. You must resolve these difficulties before you can hope to transmit packet data.

## Interfacing for Transmit

The connection of the TNC to your radio equipment for transmitting needn't be any more difficult than receiving. You may use the microphone connection to connect to the TNC's transmit audio output, though this is sometimes less than optimum.

You must carefully follow the instructions in your TNC instruction manual and observe the proper connections to your particular radio. Pay special attention to the push-to-talk (PTT) connection. Most radios will cause no problem, but some radios use a voltage too high for the components in the TNC to handle, or use an inverted voltage that could damage the TNC. If in doubt, do not hook up the transmit lines until consulting with the manufacturer or a knowledgeable person who has successfully interfaced the same type of radio.

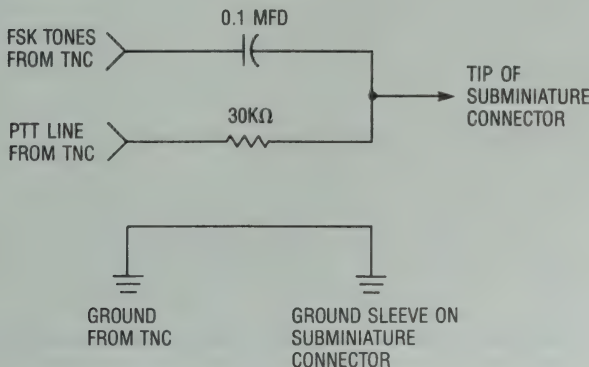
Many beginners and old-timers alike prefer to use a small hand-held type transceiver for packet activities. Usually, these units have a small, sub-miniature phone plug that carries both the microphone audio and the PTT signal. *Figure 5-11* shows a simple schematic diagram for a circuit that permits a standard TNC to be connected to such radios.

There really isn't much else to do on the transmit interface. You may find it necessary to make some adjustments to the audio level later on, but don't worry about that until your channel transmission is satisfactory.

## Your First Contact

At last, you're ready for your first packet radio transmission! If you know the callsign of another nearby station and are sure he or she is active, you are all set to go. If not, your monitoring should have revealed the callsign of one or more active stations and you can try connecting to one of them.

**Figure 5-11. All it takes is a capacitor and a resistor to properly interface your TNC to many popular hand-held radios.**



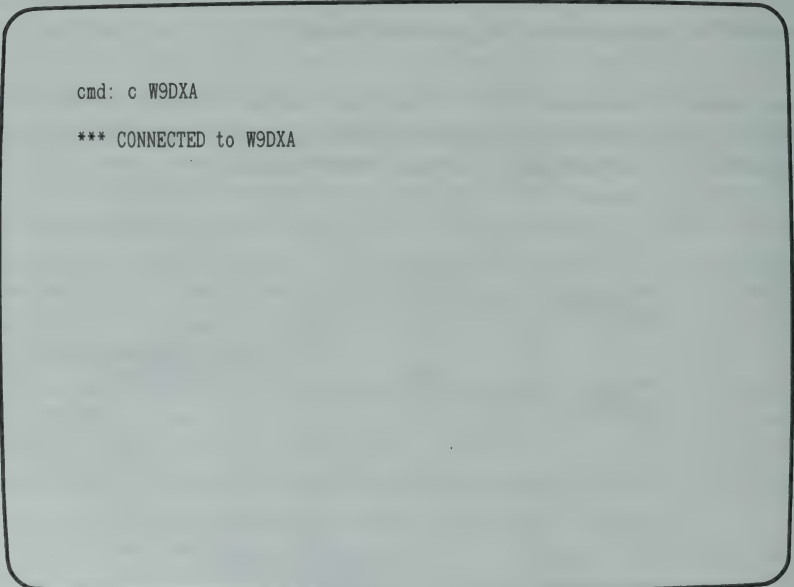


At the command prompt, it's as simple as typing **C W9DXA** which means "connect me to W9DXA." Everything else is automatic from this point. If all goes well, you'll soon see the message **\*\*\* CONNECTED to W9DXA** displayed on your screen, as shown in *Figure 5-12*. Just as the Hayes modem changes modes once a data connection is established, so does your TNC. You are normally placed into what is called *conversation mode*. In this mode, you can send and receive just about any type of plain text, but certain control characters cannot be transmitted directly because they have special meanings to the TNC. Since most keyboard to keyboard communications consists of plain text, this is the mode usually used in regular packet connections.

### Inputting Information

What do you do now? Type whatever information you wish to transmit and then press the **RETURN** or **ENTER** key on your computer. It will be transmitted error-free to the other end. If the operator is monitoring, you may get a response; however, don't be surprised if you receive nothing. Some systems will respond with a short message even when the operator is not available. We won't cover the response further right now because the next chapter details how that works.

**Figure 5-12.** The **\*\*\*CONNECTED to** message appears on your screen once contact is established with another packet station.



```
cmd: c W9DXA
*** CONNECTED to W9DXA
```

## Digipeating

If everything is going well to this point, you may want to try using one or more digipeaters before disconnecting. The technique is straightforward. At the **CMD:** prompt type **c WD9EDT v K9EI,W9DXA** as illustrated in *Figure 5-13*. Your signal is first received at K9EI, then repeated to W9DXA, and finally passed on to WD9EDT. On receive, the path is reversed. Up to eight repeater stations can be specified. In the above command, C means CONNECT and V means VIA.

While we are talking about digipeaters, here's a trick you can use if you can't find anyone to answer your connect request. From the **CMD:** prompt, type **C KA9XYZ V W9DXA** where you are KA9XYZ and W9DXA is a station you know to be active. What you are about to do is to connect to yourself using W9DXA as a digital repeater! This time the connect message will appear on your screen showing you connected to yourself. Anything you type will be relayed back to you via W9DXA. It's a great way to make sure your system is working properly when there is no one else around.

## How to Disconnect

Once you've proven to yourself that a connection is possible, it's just as important to prove that you can disconnect! First, you must return to the **CMD:** prompt by typing **Control-C**. When the prompt appears, type **D** for disconnect. A disconnect message will appear shortly and then the **CMD:** prompt will appear again.

---

**Figure 5-13. It's easy to specify relay stations when connecting to a distant operator. This \*\*\*CONNECTED to message indicates the packet is to be relayed via K9EI and W9DXA to WD9EDT.**

---

```
cmd: c WD9EDT v K9EI,W9DXA
*** CONNECTED to WD9EDT VIA K9EI,W9DXA
```

## ADVANCED INTERFACING

While many amateurs use the microphone and speaker connections on their radios for the TNC interface, it is not always the best way to accomplish the task.

After working with your station for a while, if you find that you have difficulty in establishing solid contacts with some stations, or you fear that the weak signal performance of your system leaves something to be desired, it may well be worthwhile to go the extra step and properly interface your TNC to your radio.

### Circuit Modifications

Because FM voice transmissions employ a pre-emphasis circuit on transmit, your TNC has to compensate for the difference in amplitude of the received mark and space tones. On the transmit end, all audio signals are first applied to an equalization circuit. For packet, that means that the relative amplitude between the mark and space tones becomes distorted. Since there is general agreement about how much pre-emphasis should be used, the difference can be made up on the receiving end. Some demodulator circuits demand that the mark and space tones be very close to the same amplitude for the modem to do its job properly. Unfortunately, you compound the problem by using the speaker audio on the receive end, because you introduce the possibility for additional distortion of the amplitude relationship between the two tones.

To do it right, your TNC should be interfaced not to the microphone jack, but to an audio input point just ahead of the pre-emphasis circuitry in the radio. On receive, the signal feeding your TNC should come just after the circuit that restores the proper equalization, but before any high-level audio processing is done. Audio power circuits will affect the equalization of the circuit.

It's not possible to include specifics here for accomplishing the needed interfacing. Newer radios often make it easier to do this by providing an accessory jack on the rear that already have the connection points you need. Refer to the manuals for your TNC and radio equipment for more details.

On the high frequency short wave bands, different factors come into play and are discussed in the pages ahead.

## ON WITH THE SHOW

Now that you've got most of the basics, the real fun is about to begin. In the pages ahead, you'll learn how to fine tune the parameters of your station for different situations and explore some of the special things you can do with a packet radio system.



# Operating Modes

We have come a long way and have finally arrived at our ultimate goal — using packet radio communications techniques to connect our home computer to other hobbyists, both across town and around the world!

## KEYBOARD TO KEYBOARD COMMUNICATIONS

Packet operation can take various forms and we need to spend some time looking at each of them. In the last chapter, we took a quick look at getting a terminal node controller (TNC) on the air and making a connection to another station. Since much of your time may be spent in keyboard to keyboard communications, let's begin by expanding on what we have already learned. There are many types of TNCs and each has several modes of operation. While individual units vary, the most popular TNC type is the TAPR TNC 2. Since many other units emulate the style of the TNC 2, unless otherwise indicated, the TNC 2 command set is used in the explanations that follow.

### Start Up

Once the **CMD:** prompt from your TNC is displayed on your terminal, you are ready to begin operation. You can begin communicating if you like, or you can start by making adjustments to the parameters. The default value settings are contained in the read-only memory (ROM) within your TNC. These values are used when you power up the TNC for the very first time. If you make changes to these settings, the changes are stored in battery-backed-up random access memory (bbRAM). You begin by entering your own callsign. Recall that you do this at the **CMD:** prompt by typing **MYCALL KA9XYZ** and pressing **RETURN**.

The **CALIBRATE** command and the **CALSET** command allow you to perform some tests on your TNC. On pre-assembled units you probably won't need to go through the full calibration procedure, but you should know that it is available and allows you to toggle the push-to-talk line on and off and to alternate between modem tones for testing purposes.

## Pick Your Mode

One of the parameters you can change is the **CONMODE** (connect mode). You can choose either **CONVERS** (conversation mode) or **TRANS** (transparent mode). Your TNC, as delivered, defaults to the conversation mode. We'll look at applications for the conversation mode, then those for the transparent mode.

Conversation mode is designed basically for human-to-human communications, while transparent mode is for computer-to-computer communications. Some bulletin board and special application programs use the transparent mode. At least one line of commercial TNCs also offers a Host mode for even more efficient communication between hardware.

## CONVERSATION MODE

As mentioned, the TNC automatically enters the conversation mode when you connect to another station. Once you get the **\*\*\* CONNECTED** to message on your screen, you are ready to go. Just type what you want to send and it will arrive error-free at the distant station. A message from the distant station appears on your screen as it is received. Remember that as far as your computer is concerned, the communications path is full duplex. Even though the radio path is half-duplex or simplex in most cases, the path between your computer and the TNC is still full-duplex. This can lead to some odd things happening and to some operator irritation.

What happens if you are typing a message on your screen for transmission at the same time an incoming message arrives? The chances are excellent that the incoming message will be sent directly to the screen right in the middle of what you are trying to type! There is at least one good solution to this problem, and several other practices that can at least make a bad situation better.

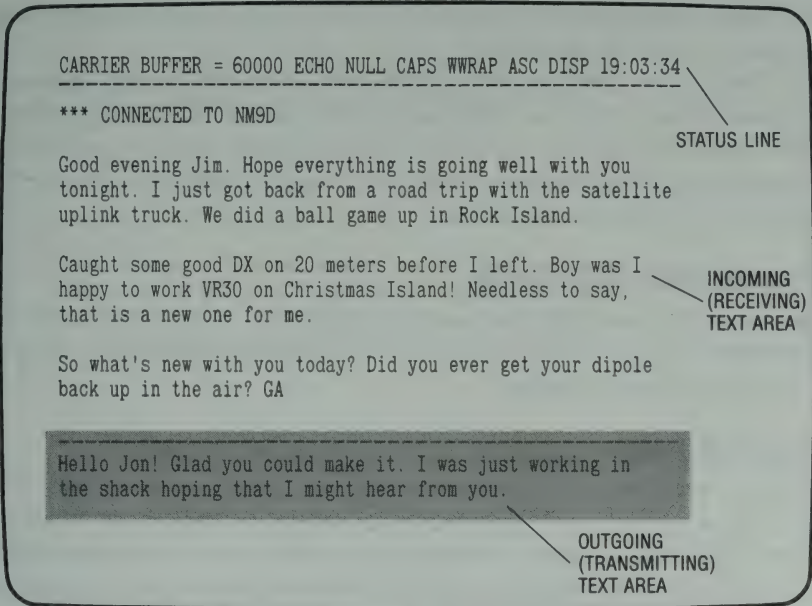
The good solution is to use a split screen terminal program if you have one. Using a split screen terminal program such as the one shown in *Figure 6-1*, you shouldn't have any difficulty in keeping things straight. Such programs create separate windows for transmitted and received data. You can see what is being received at the same time as you look at what you want to transmit.

One of the transmitting practices that helps is when stations wait for a go-ahead signal before they begin sending. This goes back to Morse operation. Generally the abbreviation **GA** or **K** is used to indicate that the station presently transmitting has completed a current thought and now is ready to receive.

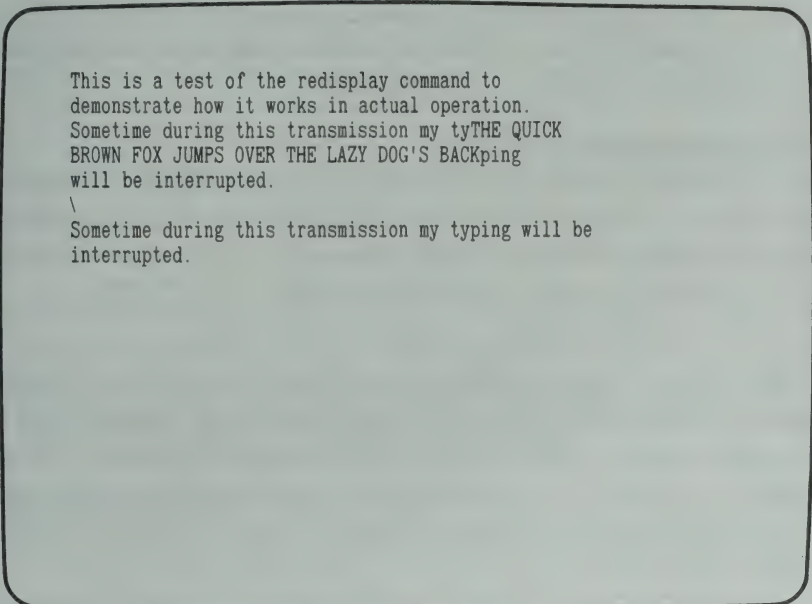
## Redisplay Command

What if the worst happens and your typing is interrupted and you aren't using a split screen program? You may get a display like that shown in *Figure 6-2*. The **REDISPLAY** command, normally **Control-R**, will bail you out. Several things happen when you use this command. First, any incoming packets that are pending are displayed on your screen. A backslash character appears on the screen and the line you started typing is displayed on a clean line. You can now pick up from where you stopped.

**Figure 6-1. A split-screen terminal program keeps your transmitted and received data displays separated.**



**Figure 6-2. Here is what can happen when your transmission is interrupted by incoming data. Pressing Control-R redisplay what you were typing on a clean line.**





The **REDISPLAY** command is one of several specially reserved commands available in conversation mode. The **Control-C** is another one you will use frequently. It returns the **CMD:** prompt when pressed in conversation mode. You can go back to conversation mode by typing **CONVERS**. You will still be connected and can continue as if you had never left.

You'll need to use the **Control-C** command to begin a disconnect sequence when you are finished with your conversation. When the **CMD:** prompt returns, all you have to do is type a **D** (for disconnect) and the process begins. In some cases, the other station may initiate the process first. In that instance you won't have to do anything; the TNC will take care of it all.

## FINE TUNING TNC PARAMETERS

There are some commands that may help you to fine tune your system. If you are having problems, or have become comfortable with the system and want to optimize it, here are some things to consider.

### TXD (Transmit Delay)

Because of the wide variety of radio equipment used in packet stations, the TNC timing circuits can be adjusted to accommodate several circumstances. While some radios can switch from transmit to receive very quickly, others are relatively slow. If the switch is too slow, the beginning of each packet will be lost and communication will be impaired. Careful adjustment of the TXD parameter can cure this problem. The trick is to adjust this value to just long enough to get the job done. Otherwise, you may be accused of using valuable channel time to send unnecessary flag signals.

### CONOK (Connect OK)

If you want other stations to be able to connect to your station automatically, you must type **CONOK ON**. When you want to restrict access, perhaps during times when your computer is off-line, type **CONOK OFF**.

### BKONDEL (Backspace or Delete)

The backspace or rub out character on your keyboard should normally result in the complete erasure of a typed character. If that doesn't happen, check the setting of the default for BKONDEL. While the default value on TNC 2 units matches most computers, TNC 1 controllers came with a default setting that did not match.

### ECHO

Are you seeing double characters on your screen when you type? If your screen looks like the one in *Figure 6-3*, you need to check the ECHO command. If it's on, reset it to off by typing **ECHO OFF** at the **CMD:** prompt. With **ECHO ON**, the TNC supplies the echo. If your terminal program is configured for a half-duplex path, it is producing an echo character within the terminal as well as receiving the one coming from the TNC.

**Figure 6-3. This is what happens when the ECHO command is not properly set on your TNC.**

```
TThhiiss iiss wwghaatt hhaappppeennss wwheenn tthhee  
EECCHH00 ccoommmaanndd iiss iimmpprooppeerrllyy  
sseett..
```

### **FRACK (Frame Acknowledgment)**

Whenever you send a packet requiring an acknowledgment, the **FRACK** command determines how long the TNC waits for the acknowledgment before resending the packet. This wait time varies depending on how many relays are involved. If you are sending packet through several distant relays and the network is unusually busy, the time required for an acknowledgment to be returned may be longer than the time allowed by **FRACK**. If so, you may be resending packets unnecessarily. If this is the case, adjust **FRACK** for a longer wait time. Finding the best value for **FRACK** will take some experimentation and will be affected by the amount of activity in your area.

### **DWAIT**

Another critical parameter is the **DWAIT** value. That's how long your TNC waits before beginning transmission after last detecting data on the channel. It is normally adjusted so that it is the same as other stations within your own local area network. If it is set exceptionally short, your station will tend to dominate the channel. If set too long, you may have trouble finding a clear time to transmit.

### **PACLEN (Packet Length)**

If you often communicate over marginal signal paths, especially on HF, which is subject to fading and phase distortion, keep your packets relatively short. While you can stuff 256 characters into each packet, it's far wiser on a marginal circuit to make

them much shorter. By setting PACLEN to 64, you keep your packets smaller and don't congest the network with long packets requiring frequent repeats.

## OTHER COMMUNICATIONS USING THE KEYBOARD

The discussion up until now has centered around keyboard communication on a one-to-one basis. Packet radio has a few more tricks up its sleeve we want to look at.

### UNPROTO Mode (Non-connected Communications) and MONITOR

One of the most common questions new packeteers ask is, "How do I call CQ on packet?" (CQ is the internationally-recognized abbreviation for "calling any station that can hear me".) The truthful answer is, "You can't!" but you can come close. If while you are not connected to another station you simply enter the **CONVERS** command, you are placed into a mode where whatever you type is packetized and sent on the channel. Since you are not connected to another station, your packets are addressed to whatever callsign appears in the UNPROTO parameter. The default value is CQ! You can change this to anything that will fit in the space of a normal callsign.

You can type a message like "This is a test, is anyone receiving me?" The message is placed in a packet addressed to CQ and will be sent once. If another station is monitoring for unconnected packets, you may receive an answer. However, most packet operators do not monitor a channel in the same way someone operating voice does, so you may not receive a response even if your message is received by another packet station. Here is where **MONITOR** is used. To see such messages, as well as connected packets, the **MONITOR** parameter must be set **ON**.

### Round Table Conversations Using UNPROTO

You may find times when unconnected transmissions are quite useful. Remember that because error-checking and correction require two stations to be connected to each other, it is not possible for other parties to join in and still ensure that all of them are receiving error-free data. For an informal rag chew, three or more stations can enter the conversation mode with **MONITOR ON** and each participant can type freely. Often the abbreviation **GA** (go-ahead) or **K** will be used to indicate the end of a complete thought. Just remember that no error checking is being done.

### Beacons

There is a special sub-set of unconnected messages that deserve a few words of their own. In the early days of packet radio, few operators used packet and those who did were always anxious to make contact with any new stations that might appear. Developers of packet software included a **BEACON** command to allow for the automatic periodic transmission of a short message.

With the growth of packet over the last several years, beacon messages have become a serious problem. The author strongly recommends that you do not use the beacon feature without a very good reason. You will only be adding to the congestion on the packet network and will probably lose a few friends in the process.



You will find it quite common for bulletin board stations to send beacon messages indicating who has messages waiting for them. They are usually sent only once an hour or so. In some localities, even this practice is frowned upon. The best thing to know about BEACON operation is that you really shouldn't be using it.

## Multiple Connections

A feature has been added in newer software that allows simultaneous multiple-connections on a single TNC. However, this is not the same thing as a round table discussion.

With this software in your TNC, you can allow a number of simultaneous connections, but each one remains a distinct and separate communication. Each connection is assigned a channel number. Unless you are talented at juggling things in your mind, and deft at operating a keyboard and constantly switching back and forth between channels, you will probably find this capability frustrating. However, it does have some useful applications, particularly with bulletin board systems.

Some work has been done with a device called a *conference bridge*. It allows several users to connect to a central point and exchange information on line while retaining error-checking and correction for all participants. At the time of this writing, most of this work is still in the experimental stage.

If just typing keyboard to keyboard was all packet could do, it wouldn't offer very much new and exciting for the computer hobbyist. Indeed, any messages received will be error free, but not much hobby communication is so critical that an occasional error in text will be a big problem.

It's now time for packet to come center stage and really begin to shine. The keyboard communication is child's play compared to the features we are about to examine.

## TRANSPARENT MODE

As mentioned earlier, packet TNCs have a transparent mode in addition to the conversation mode. In transparent mode, the data formed into packets is not processed in any way before transmission. Whatever bit pattern is sent from the computer to the TNC is transmitted intact to the other end with the same error-correction afforded the conversation mode.

Until now, we have talked in terms of sending 8-bit ASCII characters in our packets. In most cases, we have even been ignoring the eighth bit. Early in our discussion of packet techniques, we learned that the data in the information field of the packet can take any form. It does not have to be ASCII data.

Can you think of any applications for packet radio where the ability to send a bit stream would be useful? How about direct program transfer from one computer to another without the need to convert the programming code into ASCII or hexadecimal form? Imagine taking digital audio from a compact disc player and sending it via packet radio. Even digital television signal transmission via packet is possible!

The computer hobbyist is most likely to be interested in program transfer as a first step in utilizing packet's transparent transfer, so let's spend some time learning how to do it.

## File Transfer

Most telephone-based file transfer programs have error checking built into them. For packet radio, that introduces a level of redundancy that isn't needed and can cause other problems.

Perhaps one of the oldest and most widely used file transfer programs is XMODEM. This program, and others like it, divide the data to be sent into blocks of characters. A checksum is calculated and transmitted along with the block for error detection. The receiving station checks the received checksum value against its own calculation and sends an ACK signal if all is in order. You might think of it as sort of a slow and somewhat crude form of packet transmission. The checksum formula is not as complex or reliable as the CRC value generated in a packet system, opening up the possibility for undetected errors. Early packeteers tried using it, generally with poor results.

When two computers are exchanging a file over a direct telephone connection using XMODEM, there is no appreciable delay between the time when a block is transmitted and the time when an ACK or NAK signal is returned. Therefore, the XMODEM designers established a relatively short time period in which to receive the ACK or NAK, else the program assumes that the data did not make it through and tries again. After a number of retries, the transfer is aborted. That's reasonable when using a dedicated path without long delays.

Packet techniques introduce a situation not present when XMODEM was first designed. Even on telephone packet networks like those used by CompuServe, the delay in receiving the ACK or NAK is often longer than that permitted by XMODEM. Newer versions of the XMODEM program allow for the timing restraints to be relaxed to accommodate the additional delays.

On a packet radio system, particularly when several relays are used, the delay can be much longer than on a telephone network. Such long delays effectively render XMODEM useless. Experimenters developed modified versions of the program that will work, but they have also found better ways of accomplishing the transfer.

There really isn't any problem in transferring data via packet radio. Quite the contrary. It's just that the familiar tools we have used for telephone computing for so long aren't always directly adaptable to the unique situation found when using a radio channel.

One popular protocol used on packet is YAPP. It is readily available in the public domain and efficiently transfers all types of files via packet radio.

## Beginning the Transfer

Two hobbyists wishing to exchange programs via packet radio begin by setting **CONMODE** to **TRANS** to place their TNCs in the transparent mode. Then they go through a normal connect sequence.

Once connected, the operation is just as if the two computers were sitting in the same room and connected by a serial cable. The same type of communications software used to transfer a file directly from one computer to another computer in the same room can be used to transfer a file using packet radio.

Besides transferring the data directly as received from the computer, you will notice several other changes in the operation of your TNC while in transparent mode. There are no input editing features as there are in conversation mode and there is no send packet character! Packets are transmitted on a timed basis determined by the PACTIME parameter or when a full packet is waiting in the buffer to be sent. You can adjust the value of PACTIME for your particular situation.

What appears on your screen is modified too; for example, auto linefeed and screen wrap are disabled. Some of the status messages you normally see as you connect and disconnect are also disabled.

Remember that the reason for switching to transparent mode is so that data from your computer can be transmitted exactly as it comes from the serial port of the computer. In conversation mode, certain characters or bit patterns have special meaning. These would cause havoc when sending a computer program that uses those patterns, but do not have the same special meaning.

### Escaping Transparent Mode

A problem with transparent mode is that it is difficult to get out of it, since the normal **Control-C** escape code isn't recognized. If your communications program is capable of generating a **BREAK** signal, it can be used to return to the **CMD:** prompt; however, many programs do not have that capability.

The alternate is a bit cumbersome, but not unlike the escape sequence used by telephone smart modems. When using telephone modems, *Figure 6-4* reminds us how to regain control using a special character sequence. Packet operation is similar but uses non-printing characters.

**Figure 6-4. With a telephone modem, you use the +++ command to escape from transparent mode.**

This is the final portion of text received via a telephone modem. The modem needs to be returned to the command mode. We do that with a special command sequence like this.

```
+++  
ATH  
OK
```



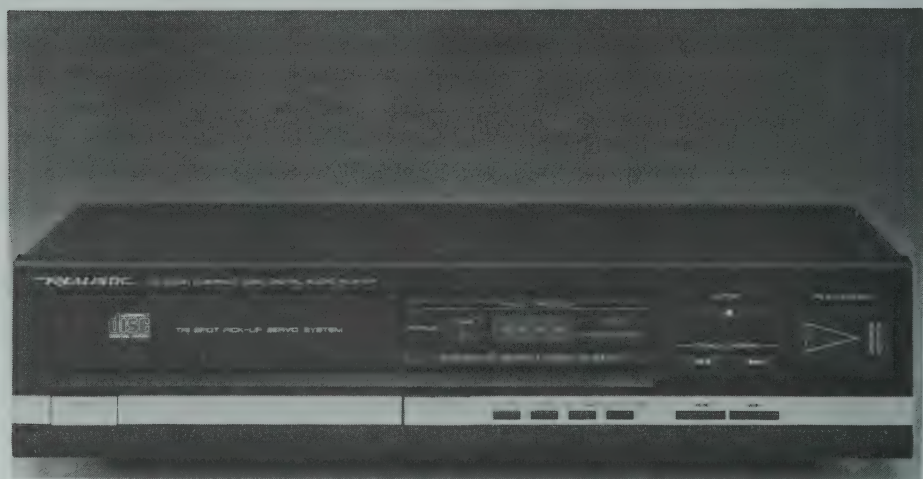
You must first wait for all of the data to be sent. In a file transfer, there will usually be one final short packet that will have to wait for the length of PACTIME before it is sent. You must then wait a period of time at least as long as that set in the CMDTIME interval, during which no characters are sent. CMDTIME is a user-adjustable parameter that sets a timer that is used in determining how long to wait before allowing the user to escape from transparent mode. Make sure the CMDTIME value is not set to zero by typing **CMDTIME** or you will find it impossible to escape from transparent mode except by powering off your TNC.

After waiting the value of CMDTIME, you type three **Control-C** commands within a single interval of CMDTIME. After an additional period set by CMDTIME during which no characters can be typed, the familiar **CMD:** prompt should return. If at any point you make a mistake and either type a character or take too long to send the three Control-C commands, the whole sequence is ignored. You will have to go through the procedure again.

### Window on the Future

The transparent mode is one of the keys to the future of packet radio. The data being sent can be computer programs, single-frame digitized pictures and graphics, and much more. Amateurs have already successfully transferred a few seconds of digital audio using packet radio. The output of a regular compact disc player like the one shown in *Figure 6-5* is a stream of digital pulses, which when converted to analog, produces the music with high fidelity. Full-motion television is entirely possible.

**Figure 6-5. Even the digital information on a compact disc has been transmitted by amateurs using packet radio.**



The problem with transmitting digital audio and television via packet is that they require a very high data rate for real time transmission. Limited bandwidth digital voice is right on the borderline of being possible with the data rates currently used in packet radio.

While it may take a little time to acquaint yourself with the transparent mode of packet radio, the results are well worth-while. There are some additional applications not quite so complicated that you will probably find of interest.

## **PACKET BULLETIN BOARD SYSTEM**

Perhaps the single largest reason for the growth in popularity of telephone computing is the availability of thousands of bulletin board systems (BBS). In most areas of the country, there is at least one BBS that can be accessed through a local telephone call. Many of these are operated by fellow hobbyists and charge no fees. Others are run by clubs or organizations that may charge a small fee for their use.

### **Packet BBS Developments**

You'll be happy to learn that thanks to the efforts of some true pioneers, a similar type of BBS operation is available via packet radio in most areas of the country. Perhaps the father of the packet bulletin board system is Hank Oredson, WØRLI. For his work in developing a special packet BBS system, Hank was presented with the annual technical achievement award in 1987, at the world's largest amateur hamfest in Dayton, Ohio. This award is presented each year to developers of innovative technology.

In the days when computer systems cost several thousand dollars minimum, Hank designed his original system around a surplus CP/M<sup>TM</sup> machine that he pieced together for several hundred dollars. Many of these machines are still in operation, though the low cost and popularity of PC clones have resulted in a need for BBS software for them. The first widespread implementation of a PC compatible system similar to Hank's was developed by Jeff Jacobsen, WA7MBL. Both programs are still very popular among hams today; so much so that programs written by other hams are often referred to as being "WØRLI or WA7MBL compatible."

Hank and Dr. Dave Toth, VE3GYQ, in Canada have developed the first BBS code that is portable among different types of computers. Written in the C programming language, it can be compiled and run on a variety of systems (including PCs) by installing the appropriate drivers.

### **Using a Packet BBS**

You connect to a packet BBS system just as you would to any other station. You can use digipeaters to reach a distant BBS, but you should only do so using great care. Some operators try to access distant systems under poor conditions which requires a lot of retries and results in misuse of the limited network now available. You are encouraged to use only BBS operations either directly accessible to you or through as direct a communications path as possible.

What you will see once connected to a packet BBS is very similar to what you would see from a telephone BBS. Due to the nature of packet radio you will notice

some differences. You will not go through the usual login sequence customary with telephone BBS. You have already been identified to the system by your callsign, so you don't need to enter it again on your home BBS. On some systems, you may be prompted to enter your first name for the user log the first time you log onto the BBS.

## Abbreviated Menu

When operating on BBS, rather than the usual verbose explanations of commands, you will generally receive either just a command prompt or a menu consisting of several choices of a single letter. *Figure 6-6* shows a typical set of transactions on a packet BBS.

This resembles the expert mode common in many telephone BBS systems. The reason it is used on packet is to make the most efficient use of the channels available. You can almost always type either **H** (for help) or **?** (a question mark) and get a fuller explanation of how things are done. Special help files are usually present on the system. You should download the help material, save it, and print it for future reference.

What features will you find on a packet BBS? They vary from system to system, but many of the features resemble those on a telephone BBS. You can send and receive messages with other users of the BBS. There is usually a download area that may include programs, but generally includes special bulletins and long messages of interest to many Amateur Radio operators.

**Figure 6-6. Here is what you would see from a WA7MBL-type BBS.**

```
***CONNECTED to K9CW VIA CMI  
  
[MBL320]  
K9CW BBS -- Urbana, IL  
K9CW 1913 UTC >?  
The "?" command lets you read this brief HELP file.  
-Type "?[LETTER]" for HELP
```



Perhaps the most exciting aspect of today's packet BBS operations is their relay ability. They can accept a message for a distant amateur and then see that it is relayed throughout the network to its final destination.

## Fido

Some computer hobbyists are familiar with the Fido™ network. Using this telephone-based BBS system, you enter a message to anyone in the world who has access to a FidoNet™. Your message is automatically routed along with any others destined for the same location through a network of Fido BBS worldwide. Your message is first stored on your local (home) system. Either on a scheduled basis or by command from the system operator, the message is forwarded to the next BBS down the line in the system. That's known as a *store and forward* operation.

With Fido-like systems, you must maintain an account to pay for the telephone usage. However, it costs far less than it would for you to call directly, since the system is optimized to transfer a large number of messages all at the same time.

## Packet Store and Forward

A packet store and forward operation utilizes the radio network and no charges are incurred! Today, the packet network is just beginning to take shape and is still going through growing pains. As a result, not every packet operator is served efficiently by the network, if at all. Reliability is not as high as telephone-based systems, but it is getting better every day.

The mechanics of sending a message to a distant station are fairly simple. You need to know the home BBS for the station you are trying to reach. In your author's case, there is no local bulletin board available, but there are several in communications range. Your author has chosen K9CW as his home BBS so any mail for him should be addressed to **K9EI @ K9CW** where the @ symbol translates literally to at. This method of addressing is far from ideal and improvements have been proposed. We will discuss them in Chapter 7.

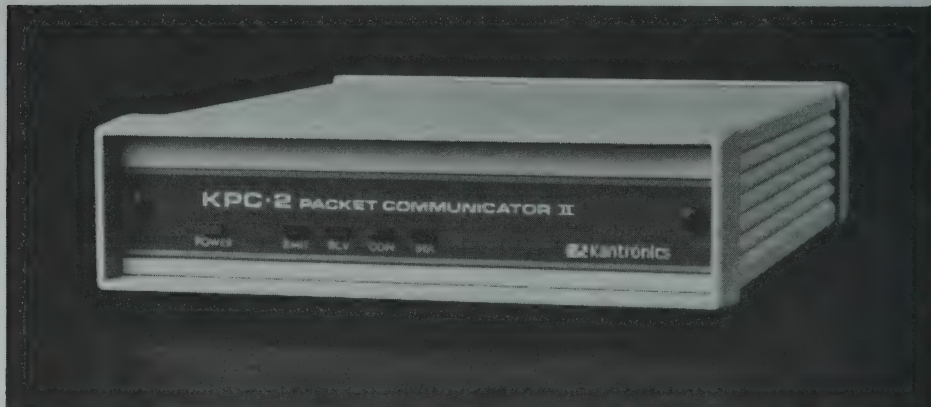
An entire chapter could be devoted to bulletin board operation alone. Since the specifics vary from system to system, it's best if you follow the advice presented here. Monitor the packet channels, and before long you will have identified one or more BBS operations in your area. Try logging in and downloading the help files. That will get you started.

## Packet Answering Machine

A younger sibling in the BBS family is the packet answering machine (PAM), sometimes called a personal mailbox. While they haven't been overly popular with telephone-based computer hobbyists, they are growing in popularity with amateur packet operators.

They really are just very small BBS systems, but are intended for an individual operator. PAMs have existed since the early days of packet. Some new TNCs, like the one in *Figure 6-7*, have a PAM built in to their programming. Most newer TNCs have implemented at least some simple features that are PAM-like. The TNC 2 units and most late model TNCs include the option of programming a connect message.

**Figure 6-7.** The Kantronics Packet Communicator II includes a built-in PAM.



*Courtesy of Kantronics*

When another station connects to you, the TNC automatically transmits a brief message that you have stored in the RAM in your TNC. If you have a communications program with a buffer or a save-to-disk option, whatever incoming message is sent can be stored for you to read on your return. So you don't even have to be there to receive your messages! When used in combination with the date and time stamp options on some TNCs, you'll even know when the message was received.

Many programmers have taken this one step farther and have included the ability to store outgoing messages. When a station for which you have left a message connects to your TNC, the operator is prompted and told how to retrieve the message. Some systems even allow for file transfer.

Some PAMs are designed so that larger BBS systems can automatically transfer messages directly to you without you having to check in! Usually such transfers take place during low activity periods (like the middle of the night). Your program needs to be able to recognize the BBS when it connects and then furnish the prompt characters it is expecting to initiate the transfer.

## VHF VERSUS HF

Finally, we need to discuss the differences in operation on VHF radio frequencies and HF radio frequencies. Virtually all of our discussion has assumed that you are using a packet radio station operating on one of the line-of-sight VHF or UHF frequency bands and using AFSK transmission over an FM radio channel. Indeed, that's where most of today's packet activity takes place, but some exciting possibilities exist for packet in the shortwave spectrum where signals can travel around the world.

## VHF Activity

The activity on VHF makes packet operation simple. No tuning is required since FM activities occur on specified channels. It's as simple as turning a dial or setting a digital channel display to the proper channel.

Although operation on VHF and UHF is limited in distance, paths are generally very reliable, particularly for communications up to a few dozen miles. While conditions vary with weather and other conditions, they do not affect normal VHF operation much.

On the two-meter (145 MHz) band, a data rate of 1200 bauds is the choice of most people. The popular TNCs support this speed. Some operation has occurred at 2400 bauds, but it hasn't yet caught on. On higher frequency bands where the permissible bandwidth is greater, experimenters are already sending packets at 9.6 and 19.2 kilobauds! The equipment for higher speeds still needs development so it may be a few years before most of us get to enjoy the advantages of the higher speeds.

## **HF Activity**

When we switch to the HF bands, radio spectrum becomes even more precious and international regulations limit the bandwidth available for digital transmissions. As a result, packet activity occurs at 300 bauds. While that may seem quite slow, it is still considerably higher than 110 baud ASCII which was the highest speed generally used on HF prior to the development of packet.

So, one of the first things you need to do to enjoy HF operation using your packet TNC is to switch the speed of the radio channel to 300 bauds. On TNC 2 type units, that's accomplished by setting the DIP switches on the back of the unit. With some TNCs, you may use a special command like **HF ON** or **VHF OFF**.

The demodulator circuitry in the TNC 1 and 2 has been optimized for operation on VHF FM channels. Remember the equalization problems we discussed in the last chapter? While the filter in the TNC 1 and 2 helps correct for that situation on VHF, it can actually aggravate the situation on HF since the same pre-emphasis is not used. Many newer TNCs include hardware better suited to HF operation, but the TNC 1 and 2 can be modified for optimum operation on HF. While the changes are not extensive, the beginner is apt to shy away from making them. There is also no way to easily switch between the two even if modification is made.

## **Tuning the Packet Signal**

High frequency transmissions are difficult to tune in by ear. The TNC 1 and 2 do not include any type of tuning indicator since they were mainly intended for operation on VHF channels where careful tuning is not required. Most beginning packet operators find it difficult, if not impossible, to successfully tune a packet signal by ear alone.

An external tuning indicator can be added to aid tuning. These add-on units are now available commercially, so you can either build one or buy one at a later time. A tuning indicator is included in the package with many multi-mode units.

## **HF Interface**

Connection to a HF station isn't much different than it is for VHF operation. For HF, however, you apply the audio frequency-shift-keyed (AFSK) transmission tones to a different type of transmitter. On FM, the AFSK tones retain their original identity over the radio path. On HF, the AFSK tones are applied to a single-side-band trans-



mitter. The result is that the AFSK signal is transformed into a frequency-shift-keyed wave. The changing audio tones from the TNC result in an actual shift in the transmitted frequency when applied in this manner.

While it is important when tuning RTTY or ASCII signals to make sure you do not invert the mark and space frequency, packet does give us a break in that respect. The encoding scheme used to shift between the mark and space tone is based on whether the data bits *change* from a 1 to a 0 or from a 0 to a 1. If the next transmitted bit is the same as the one before it, no shift between mark and space tones occurs. This is called *non-return to zero-inverted* (NRZI) signalling.

Since the TNC really doesn't care whether the shift is from mark to space or space to mark, just that there is a shift, we can tune an HF packet signal on either the high side or the low side (upper or lower sideband).

### ***Propagation Effects***

Most activity on the HF bands takes place on the 20 meter Amateur band. It is allowed on all HF bands. Novice and Technician class operators may use HF packet in the 10 meter band only where they have full digital privileges.

The choice of 20 meters is based on a number of factors. It is the most reliable band amateurs have for day-in and day-out long distance communication. While other bands will work well on some days in some seasons, 20 meters is the best performer overall.

The peculiarities of HF wave propagation can work against data transmissions. The optimum frequency for data transmission of HF at any given time is just below the so called maximum usable frequency (MUF). The reasons for this are beyond the scope of this book, but keep in mind that distortion of the signal will increase as the frequency deviates from this value. As a result, packet transmissions on the 160, 80 and even 40 meter bands, especially at night, can be all but futile.

Look just above 14.100 MHz for packet activity. You'll find a network of long-haul BBS systems operating at 14.109 MHz. These are not generally available to individual operators. They serve as a backbone network to move traffic over long distances.

As the popularity of packet operation increases, look for activity on other HF bands. As of this writing, there is growing activity on 10.145, 10.147 and 10.149 MHz in the 30 meter band and on 7.092 MHz in the 40 meter band.

### **SUMMARY**

With packet radio, you can chat with a friend by keyboard, receive messages even when you aren't home, send greetings to a station across the country at no cost, transfer computer programs without tying up the family phone line, and experiment with advanced digital communications modes involving picture and audio transmission. The applications for packet are limited only by your imagination. Later chapters explore some of the more fascinating possibilities.

# Networking

## A BIT OF HISTORY

When telegraphers began wiring terminals together, they started with the simplest of networks. The first connections were made directly from one telegraph office to another. As the system grew, it became awkward to have a separate circuit to each distant point. In some cases, there was a large duplication of effort and resources.

Messages traveled over long distances by being relayed from station to station. Where the telegraph wires weren't up yet, a Pony Express rider might carry the message on its final leg for delivery. At first, all the relaying was done manually. That is, a message was received by ear at one station, written down and later retransmitted by hand over another circuit. Inventors soon discovered a way to build electrical relay circuits to eliminate the need for human intervention. Finally, the idea of centralized switching centers became popular.

## Switching Networks

Our modern telephone network is based on the foundation laid by the early systems. At first it was necessary for all calls to be routed to an operator, who completed the connection with manual plugs in a switchboard. Direct dialing came later, and automation made the system more efficient.

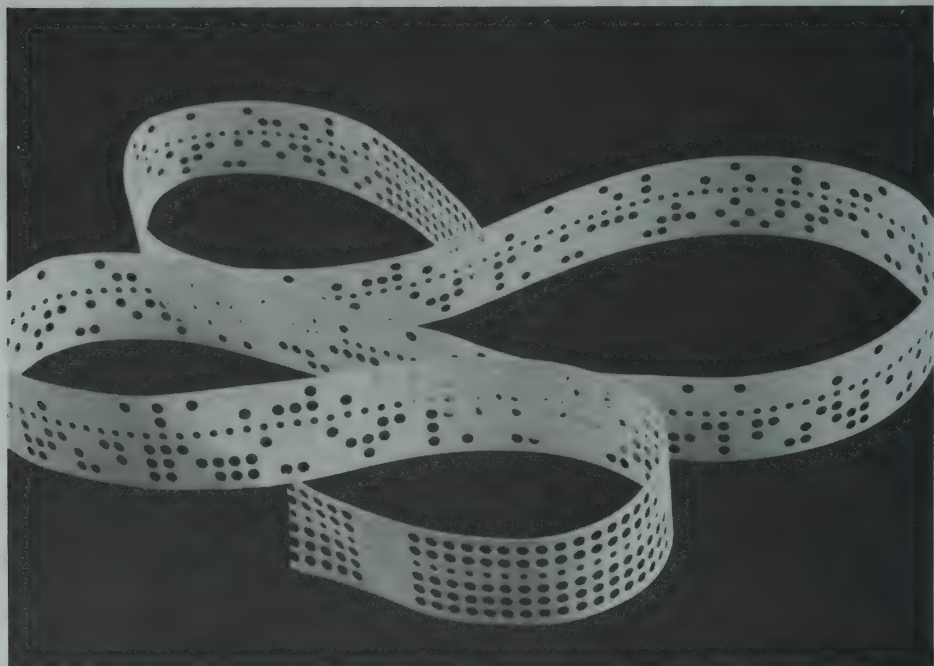
Throughout the course of history, engineers working with mathematicians have developed some excellent ideas about how to make networks of any kind work efficiently. When you finish with this chapter, you won't be able to discuss networking on the same level as a professional network analyst, but you should have an appreciation of where the packet radio network is today and where it is headed.

## Store and Forward System

The history of amateur radio networking largely parallels development of earlier wired communications systems. At first, wireless operators used Morse code and relayed messages in much the same way as early telegraphers. The main difference was that the wire was replaced by radio frequency transmissions. Perhaps one of the first modern forms of store and forward relaying using radio teletype circuits was made possible by using punched paper tape. The incoming message caused a

mechanical punch to punch holes in a paper tape, effectively storing the message. The message was later sent using a mechanical device to read the paper tape and retransmit the information it contained. *Figure 7-1* shows the paper tape and the code of holes punched in it. The Baudot code is used for the data.

**Figure 7-1. Data was stored on paper tape and later forwarded when using early radio teletype systems.**



## RADIO MESSAGE NETWORKS

Strictly speaking, amateur radio message networking has gone on for more than fifty years. All of it was and still is being accomplished mostly by human beings. Messages are collected on a local level, passed to a central state-wide network, relayed to a regional level, delivered between regions, passed back down the hierarchy to the local level, and finally to the destination.

Theoretically, all of this networking should work pretty well, and it does it many cases. Since amateur radio is a hobby and the message handlers are volunteers, difficulties develop when people lose interest, go on vacation, or have equipment failures. Even varying radio propagation can cause a back up or delay in traffic reaching its final destination.

## Automating the Network

What has been missing is a reliable network that takes advantage of automation to overcome some of the problems inherent in a human network. Packet radio lends itself to such an automated network.



Let's begin with the first packet operators. In many cases, an experimenter might find that he or she was the only packet station for many miles. Some of the early packeteers interviewed by the author say that they built packet stations to loan to other hams just so they would have someone with whom to experiment! When two or more people were on packet in the same area, they could then begin exchanging both keyboard to keyboard messages, and more exotic communications if they wished. The communications path was always direct. No repeaters were used. There were no store and forward bulletin boards.

When digipeating became a feature of TNC software, packet enthusiasts found their range extended. In the true amateur spirit, hams began looking for ways to maximize the use of digipeaters.

## Basic Local Area Network

As long as all the stations within a given area can communicate directly with each other, an effective *local area network* (LAN) exists. Variations in power levels, antennas, and topography cause differences and make it more difficult to communicate with some stations than with others.

When FM voice first became popular among radio amateurs a similar problem existed. By placing a centrally located repeater station on the air, the effective communications range and communications reliability for all stations within its coverage were greatly increased. Mobile stations could be heard just as well as more powerful base stations and the effective range of walkie-talkies was greatly increased.

## Local Digipeater

A centrally located packet digipeater acts in a similar fashion to create a local area network for packet radio. Sometimes it is a packet station located at a superior location and is dedicated to digipeating only. A few serve both digipeating and BBS functions. In some areas of the country, like the author's, there is no dedicated digipeater. Low power operators rely on the extended range of more powerful stations who generously allow digipeating through their equipment.

It isn't necessary for a packet LAN to have a central digipeater, but it does facilitate connecting the LAN into the overall network. A typical LAN arrangement is shown in *Figure 7-2*. Often airport identifiers, such as SPI for Springfield, Illinois, are used to identify the key nodes in a packet network.

## Wide Area Network

There is a variation on the LAN sometimes used in sparsely populated areas of the country. Rather than relying on modest digipeaters to link amateurs together in several different local area networks, a single super-repeater is located where it can reach much farther than the usual LAN digipeater. Some choose to call such an operation a *wide area network* (WAN). Traditionally, a WAN is a collection of interconnected LANs, but in amateur applications the terms tend to blur.

**Figure 7-2. A local area network (LAN) is a collection of data stations located close to each other.**

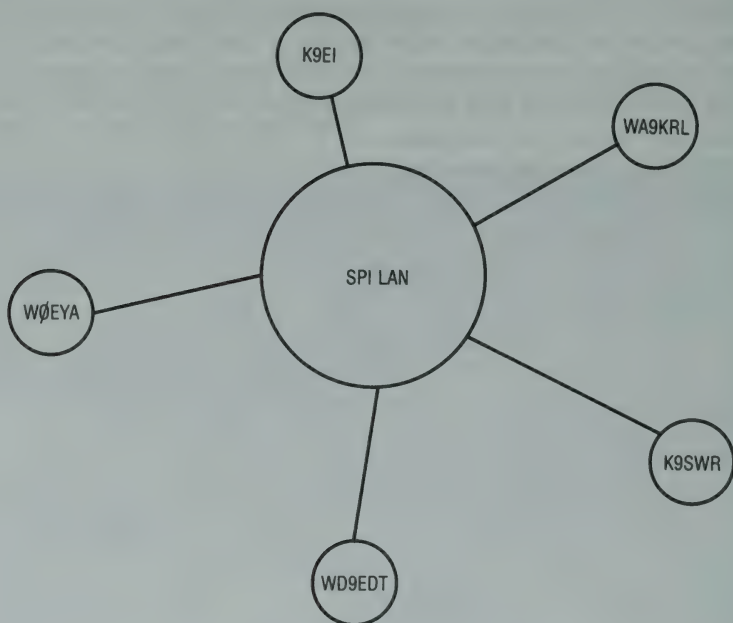


Figure 7-3 shows a WAN in your author's area. Effectively, all the operators are members of one very large LAN. The problem is that when you start relying on a single system located many miles away, you introduce a very low reliability factor. Propagation effects, weather conditions and other anomalies affect the day-to-day operation of the entire WAN.

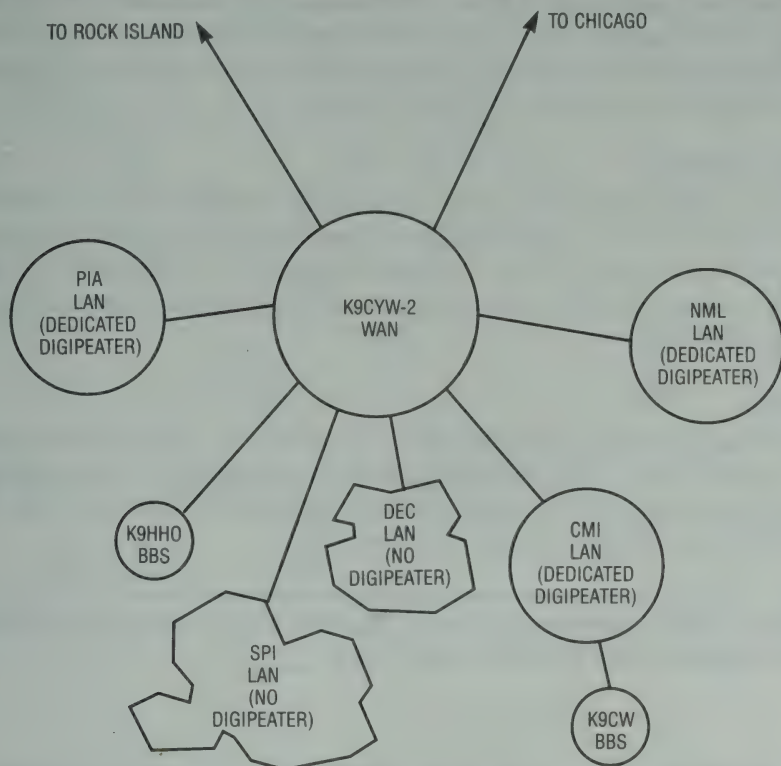
The reality of packet networking today is that most of it relies directly on the digipeating capabilities in level two of the AX.25 protocol. Particularly in large populated areas, that causes some big problems. Let's see why.

## Channel Congestion

In the early days of packet radio, nearly everyone operated on the same 2 meter frequency. That made it easier to find other packet stations and made relaying of messages possible using limited resources. As packet has grown from well under 1000 original participants to an estimated 30,000 world-wide today, it has become increasingly difficult to handle all the traffic on a single channel.

Here's a situation typical in your author's local area. Two stations located no more than a few miles apart are engaged in keyboard to keyboard communication. They are close enough that they do not require any digipeating. Since they are relatively slow typists, it takes a long time before they have enough information in the buffer to force a packet to be sent. At the same time, Station #1, KA9XYZ is trying to connect to Station #2, NQ9X located about 70 miles away. Even for a well equipped station, that's too far to reliably maintain direct communications. At least

**Figure 7-3. A wide area network (WAN) is a collection of interconnected LANs. Some may have dedicated digipeaters while others may not.**



one super-repeater must always be used and sometimes additional relays must be relied on to make it. The more repeaters that are used, the busier it makes the channel.

If all the packet stations on the network are properly adjusted, this still shouldn't cause any significant problems since packet is designed to effectively share channel usage. As the number of stations using the frequency increases though, the opportunity for collisions between stations rises dramatically.

## Hidden Terminals

It's bad enough when most of the stations on the frequency can hear each other directly, but when some of the signals are hidden from view of one or more of the stations, unintentional collisions become very common. If Station #1 uses a WAN type digipeater 50 miles away that has a communications radius of about 75 miles, that means that the digipeater can hear signals as much as 125 miles from Station #1's location. Station #1 can't detect those signals directly, so when another station within the coverage area of the digipeater tries to send a packet through the same digipeater Station #1 is using, Station #1 doesn't know the frequency is busy and also will attempt to send a packet. The digipeater at the WAN detects both signals simultaneously. A collision results and neither of the packets gets through. Both stations wait for an ACK that never comes from the far end before trying again.



In some parts of the country, many LANs and WANs all operate on the same frequency. Using *Figure 7-4* as an example, you can see that the coverage areas overlap and some stations are “hidden” from reception by others even though they are on the same frequency. Some WANs often hear other WANs 100 or more miles away. The potential for interference is staggering. A partial cure for the problem is not as difficult as it might seem. Let’s see what it is.

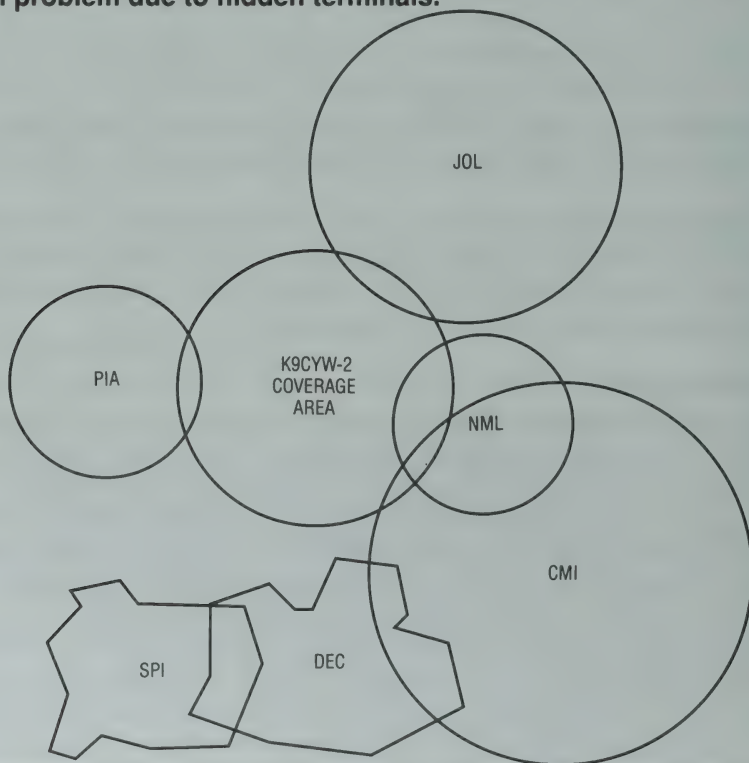
## Multiple Channels

If the LAN and WAN frequencies are separated, they no longer cause interference to each other. If the LAN in the example above operated on 145.03 MHz, for example, and the WAN continues to run on 145.01 MHz, they won’t collide with each other. They also won’t be able to communicate with each other without some additional hardware called a gateway.

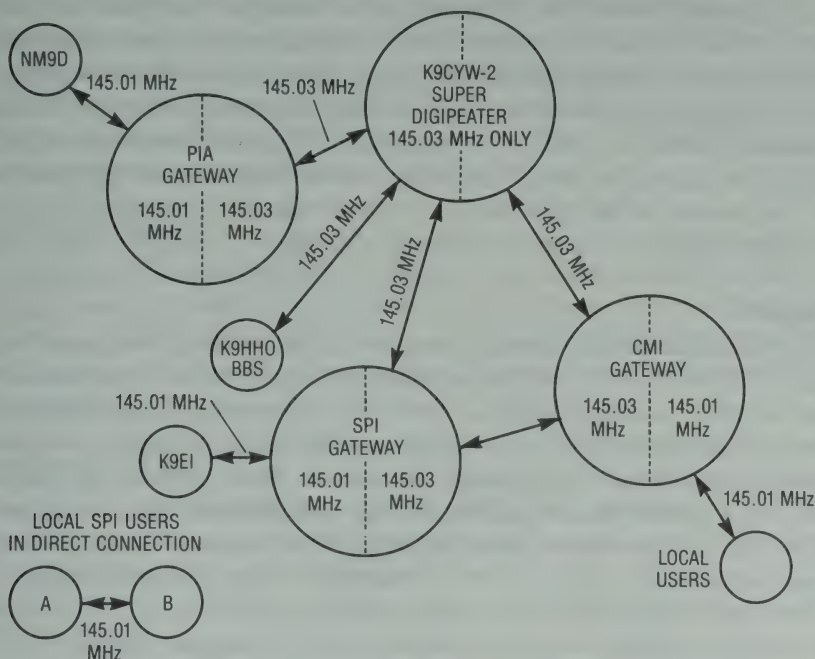
## Gateway

If a special packet station is set up in each LAN to serve as a gateway to the WAN, then we can have the best of both worlds. This is accomplished by using a special TNC that has two or more ports and a radio and antenna system for each port. *Figure 7-5* shows how such a system might be implemented.

**Figure 7-4. With everyone operating on the same frequency, congestion is a real problem due to hidden terminals.**



**Figure 7-5. The gateway arrangement moves long haul traffic to a separate frequency.**



Returning to our example, the keyboard-to-keyboard local communicators stay on the LAN channel just as they always have. Station #1 does too, but now rather than specifying the distant WAN digipeater directly, Station #1 uses the callsign of the special gateway station. When Station #1 starts sending packets, they are received on port one of the gateway station on the LAN frequency and then immediately repeated through port two to a radio and antenna operating on the WAN frequency. No longer do individual stations run the risk of interfering with the wide area repeaters since they are now on different frequencies. All the long-distant communicating takes place on frequencies separate from the LAN, leaving it clear for the maximum number of users.

This concept is not restricted to just two levels. Multiple levels of networking can be used. When properly done, packets arriving at each level can be bundled together for more efficient transmission to the distant end.

The system just described is in use in several areas of the country. Amateurs in the Huntsville, Alabama area helped to successfully pioneer the concept, basing their system on early work by amateurs in both Florida and California. The Huntsville amateurs have a fairly reliable path to points as far away as Atlanta, Georgia. Many of the metropolitan areas in Texas are linked via TexNet.

## Cross Band Trunks

While the different network levels need only be separated in frequency, there are some advantages to also using bands other than 2 meters for the trunks between networks. In the Huntsville and Atlanta areas, for example, the 2 meter band is already very heavily used for other modes of communication. These groups elected to use 450 MHz for their long-haul networking. Other areas of the country use 220 MHz. In the future, microwave bands at 1.2 GHz and above will be commonly used.

Besides offering a separation of frequency, UHF and microwave bands offer the possibility for higher data rates. Restrictions on bandwidth are not a problem at these higher frequencies, so the upper levels of the network can communicate at rates much higher than the 1200 bauds common on 2 meters.

## Throughput

While we are talking about speed of transmission, let's look at *throughput*, the measure of the real or effective transmission data rate. While each packet station in a 2 meter network is communicating at 1200 bauds, there are a number of factors that decrease the effective speed. To communicate using packet techniques, we have to set aside part of each packet for header information. While it helps to get the packet where it is going error-free, it does not actually communicate whatever data we are trying to send. The header and other non-message information contribute to the *overhead*, which takes away from the overall effective rate of transmission.

Retransmission of a packet because of data error, collision, or whatever reason also decreases the effective communications speed. Throughput, therefore, is affected by these factors. The more digipeaters you use, the lower the throughput. The greater the number of collisions, the lower the effective baud rate.

The multi-port digipeaters or gateways implement only the simplest part of the level three of the OSI/RM model shown in *Figure 4-3*. From a protocol standpoint, they are still operating in level two. As a result they simply pass data through, with only the radio frequency converted. That's not to downplay the improvement in performance they provide. It's just a way of saying things can be done even better.

## Level Three Networking

The next improvement is to calculate the validity of received packets. With this system, when a packet becomes distorted during relay, the repeat can come from the last point where the data was valid, rather than having to try and do it again from end to end. This greatly improves the overall network throughput.

Further enhancements include allowing the network to store, and to select the best path between itself and a distant LAN. Operation might work something like this:

Station #1 wishes to connect to Station #2 as before, but does not know the path to get to station #2. Station #1 issues a connect request to his local network server node. Let's say it identifies as SPI. He knows only that Station #2 is served by the network node PIA (Peoria Industrial Area). Once connected to his local server node, Station #1 simply types the command that in plain language means "Connect me to



Station #2 at the PIA node.” The hardware/software combination at Station #1’s local node checks its routing table and attempts a connection using the best path available. How does it know what that is? The server node constantly monitors the network channel, makes note of what it hears and when, and updates its routing table. If no path is currently available, it can respond with a message to that effect.

The specifics of the protocol used in higher levels of networking has not been specified. Different groups have proposed different standards. Just as in the early days of packet, the variations are sometimes relatively minute, but very seldom is one system compatible with another one.

## NETWORK HARDWARE

The TAPR group undertook a project several years ago to develop the hardware and software for a *network node controller* (NNC). As envisioned, four very flexible packet ports would be available. The unit is still in the experimental stages at this point, and no agreements have been reached on how the software will specifically handle each port.

## NETWORK PROTOCOLS

Several terms will crop up as you read about networking for the future. You will find that there are proponents for each of two major types of networking protocol: *virtual circuits* and *datagrams*.

### Virtual Circuits

Virtual circuits use an abbreviated address field once a connection is actually established between two stations. Using this protocol cuts down on the overhead, but forces each packet to take exactly the same path from end to end throughout the duration of one entire connection session. The experimental virtual circuit protocol is based on the CCITT Recommendation for X.25 packet layer protocol.

### Datagrams

Datagrams contain complete addressing information on each packet transmission. That increases the overhead, but allows the path to be changed at any point during a connection session. If a path fails or a piece of hardware goes down, the connection can be routed around the failure.

One system based on datagrams follows the Transmission Control Protocol/Internet Protocol (TCP/IP). The IP portion is proposed for level 3, the network level of the OSI model, while the TCP portion would be used for level 4, the transport level. The advantage of TCP/IP, which is used by the Federal government, is that it is designed to deal with unreliable lower protocol levels such as noisy radio paths.

## BBS NETWORKS — A SPECIAL CASE

We need to spend just a bit longer exploring the store and forward BBS network in place today. While the operation of such a system does not qualify as networking in the sense we are discussing it here, it seems appropriate to get a better understanding of how the system does work.

You have already learned how messages are entered into the BBS system. To automatically send a message to a distant station beyond your normal communications range, the BBS system you use must be compatible with forwarding procedures established in the WØRLI system. While many, if not most, packet BBS systems meet this qualification, not all do.

## Routing Tables

Once the message has been posted, the BBS software checks the destination callsign (the one following the @ symbol) to see if it is in its routing table. If so, there is no problem. The message will be forwarded at the next opportunity. If no match is found, it will probably be necessary for the system operator (SYSOP) to manually intervene and determine how to route the message. That's the first place something can go wrong. In years past, amateur callsigns signified in which part of the country a station was located. For example, the ninth call area is used for Illinois, Wisconsin and Indiana. Unfortunately, under current rules, the FCC does not routinely issue new callsigns when people move from one call district to another. As a result, many W3 station operators now live in California even though the sixth call area is reserved for that state. That makes it difficult for a SYSOP to know how to route a message. Even WØRLI himself (a midwestern callsign) designed the BBS system while living on the East Coast. He now resides in California!

## Long-Haul Network

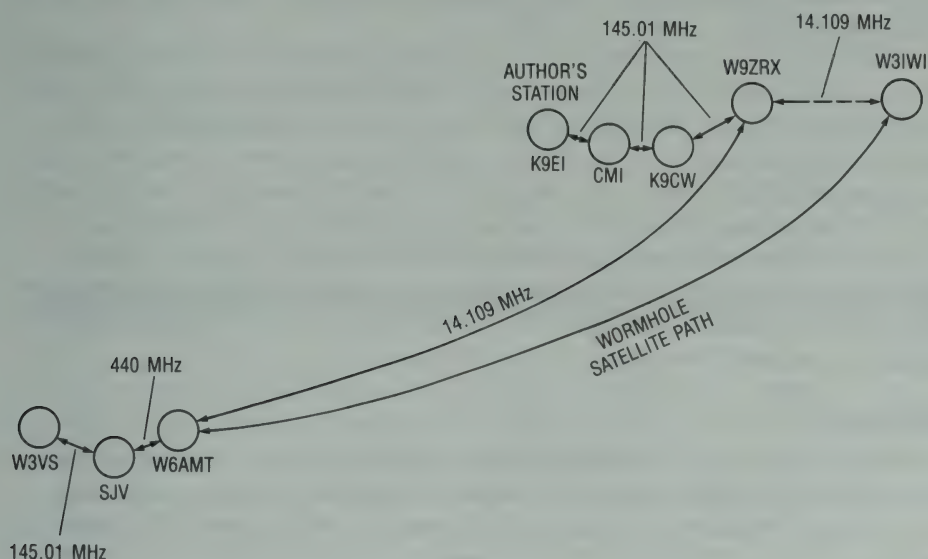
If the message is destined for someone nearby, the BBS where you left it may deliver it directly to the home BBS of the intended recipient. If not, the message most likely will be routed to one of several dozen backbone stations which pass traffic over great distances. These stations usually operate on both VHF and HF frequencies. In *Figure 7-6*, you can examine a typical path from your author's station in the midwest to one on the west coast. (The Wormhole satellite path is discussed later.)

A message from your author's station addressed to W3VS in California is first sent to a BBS. The K9CW BBS is accessed by using the network node in Champaign, Illinois (CMI). Next, the message is relayed to W9ZRX in Indiana who participates in the long-haul backbone network. The message is normally routed to W6AMT in California, but could alternately be routed to W3IWI in the Washington, D.C. area to take advantage of the satellite path to California via the Wormhole (explained later). Once the message arrives at W6AMT, it may be relayed via 440 MHz link to the San Joaquin Valley node (SJV) and finally to W3VS.

While message handling is an Amateur tradition, automated operation of Amateur equipment is a relatively new concept. When Amateurs first began unattended BBS operations using packet radio, questions were raised as to the legality of such operations. The concern was for misuse of Amateur frequencies and possible interference.

After some hoopla, the FCC decided that unattended operation was fine on VHF, but banned it from the HF frequencies. At the time of this writing, the FCC has granted a special temporary authority to a group of stations operating under the auspices of TAPR and the ARRL that allows unattended operation on 14.109 MHz.

**Figure 7-6. Here's how messages flow on one of today's BBS networks.**



The FCC was persuaded that a controlled experiment would answer the questions they had about possible harmful effects of such operations. The system has been in place for many months with no serious problems or abuses.

The stations, operating in an automated fashion under the special STA, exchange messages only between themselves. They are usually not open to the general user. Their sole purpose is to pass messages over long distances where they can be ported back to VHF for final delivery.

## Need for Better Addressing

As the amount of traffic has grown, the need for a better addressing and routing scheme has surfaced. Perhaps the leading contender right now involves using the ZIP code of the destination station for routing. Telephone area codes, ARRL sections, and other schemes have also been proposed. Each has problems inherent in its use, but the ZIP code idea seems the likely winner.

The problem may be answered very shortly by some now affordable modern technology. A firm specializing in printed listings of amateur names, addresses and callsigns is currently cooperating in an experiment on a packet BBS where the entire FCC amateur data base is stored on a compact disc. The BBS can then access the rest of the information based on callsign alone.



## SATELLITES AND THE WORMHOLE

Other innovative approaches are being used by Amateurs today that qualify for discussion under the subject of networking. Perhaps the most intriguing is the use of Amateur built communications satellites. That one deserves its own chapter and will round out the book.

With the help of a commercial communications company, Amateurs on the east and west coast now have a high speed, very reliable link available twenty-four hours a day. Refer to *Figure 7-6* again and you'll notice that an alternate path was indicated through the satellite link. In some cases, it is actually more expedient to relay messages from the midwest to the east coast first, and then send them via the satellite link to the west coast. A spare data channel on a commercial geosynchronous communications satellite has been donated for Amateur use. A gateway station located on each coast at the commercial site relays properly addressed packet transmissions to standard Amateur VHF and UHF frequencies. This path is affectionately called the Wormhole.

## SUMMARY

Packet radio has grown from an infant just a few years ago, to a viable communications medium today. Particular attention must be paid to creating the best network we can design within the limitations of the Amateur system and hobbyist pocket-book.

An Amateur experimenting in packet data communications has the chance to be an active participant in setting the standards for the future in Amateur packet communication. Higher baud rates, greater throughput, and reliability are being made possible by the work of hobbyists today. While many Amateurs are very good at the radio end of the hobby, they are not necessarily equally qualified with respect to their knowledge of data communications and networking. It's a ideal situation for an advanced computer hobbyist who wants to make a real contribution. And for the rest of us, it's a lot of fun to experiment with what is already available and enjoy each new addition as it comes along.

Amateur Radio has a long tradition of public service in times of disaster or emergency. Emerging packet networking technology will help Amateurs to better serve their fellow citizens when called upon to provide public service communications.

# The PC as a TNC

Without a doubt, the most popular way of operating on packet radio today is through the addition of a dedicated terminal node controller (TNC). Since a TNC is nothing more than a specialized computer, many hobbyists ask why a home personal computer (PC) can't be programmed to act just like a TNC.

The answer is that it can be. It is being done by some individuals, mostly by owners of older models of Radio Shack's TRS-80 machines and the Commodore 64, because software exists for these computers to perform most of the functions of a hardware TNC. In any case, it's not an easy task to accomplish.

## DOING IT ON A TNC

In Chapter 5 we took a look at the basic hardware components in a stand-alone TNC. Let's spend a moment looking a bit more deeply at what each of the elements in a TNC is expected to do. Since the TNC 2 design is the most popular, let's use it again for our example.

At the heart of any computer is a processor. The TNC 2 uses a Z-80A microprocessor chip. All operations are processed through the Z-80. It is in control of everything that happens in the TNC.

Like any processor, the Z-80 must have a clock signal to function. The TNC 2 clock runs at a frequency of slightly more than 2 MHz with standard grade components. If integrated circuits of higher specification are installed, such as a Z-80B and support chips, a clock rate of almost 5 MHz can be selected. Remember that the faster the clock rate, the more operations the CPU can perform in any given time period.

In addition to the CPU clock, provisions must be made for the user port clock. In the case of the TNC 2, it is switch selectable to accommodate a variety of baud rates and runs at 16 times the user rate.

Even the special MF-10 switched capacitor filter used in the modem requires a clock signal. It operates at 153.6 kHz.

## Program In Memory

In order for the TNC to perform as expected, the machine instructions must be stored in non-volatile read-only memory (ROM). A minimum of 8K of ROM is required, though it can be expanded to 16K or even 32K. Current TNC 2 units contain 32K of ROM as standard. All of the instructions necessary to properly implement the AX.25 protocol must be contained in this ROM. While even a 32K program isn't that large, keep in mind that in a hardware TNC, many functions are performed by special chips that contain their own programming. That's important when we look at implementing TNC operations in a home PC.

In addition to the non-volatile memory, we need someplace to store information and results on a temporary basis. The TNC 2 contains 16K of random access memory (RAM) which can be expanded easily to 32K.

## Communications Port

One of the chips used to support the Z-80 processor is the Z8440, a serial input/output device. It is configured as a universal asynchronous receiver-transmitter (UART). This device is used to interface the TNC to the serial port (usually an RS-232 port) of your personal computer. The UART translates TTL level signals inside the TNC into voltages appropriate for RS-232 communications.

In the TNC 2, the UART also works with two specially-programmed memory chips called a *state machine* to perform the HDLC (High-Level Data Link Controller) functions that make packet transmission what it is. Other TNC designs use special HDLC chips. The TNC 1 design uses a Western Digital 1933/1935 while the Vancouver TNC uses an Intel 8273. The Zilog 8530 is used in some special applications which we will explore in a moment. It is very important to remember that an HDLC chip is really a small computer in itself. All of the programming necessary for properly encoding and decoding individual packets is built into the HDLC chips, relieving the main processor from that responsibility.

## Modem

Virtually all TNCs include a modem. The term is used here in the most traditional sense to refer to the circuitry that actually converts the digital computer signals into tones for transmission and converts incoming tones to digital signals that the computer can process.

The TNC 2 uses a combination consisting of three main chips. The XR2211 is a *phase-locked loop* (PLL) demodulator circuit used for receive. The MF-10 provides filtering for effective use of the TNC with FM transceivers. For transmitting data, the companion XR2206 produces the modulating tones.

## Additional Components

While these are the major components, there are numerous additional chips required to ensure proper signal levels and to interface the various portions of the TNC. The proper voltages must be supplied. Battery back-up is provided for the RAM so that critical data is not lost during temporary power outages.



## DOING IT ON A PC

As you can see, regardless of how simple an outboard TNC appears to the user, it is a very complex microcomputer in its own right. Over the years it has been refined and compressed. Very large scale integration (VLSI) technology has reduced the number of components significantly.

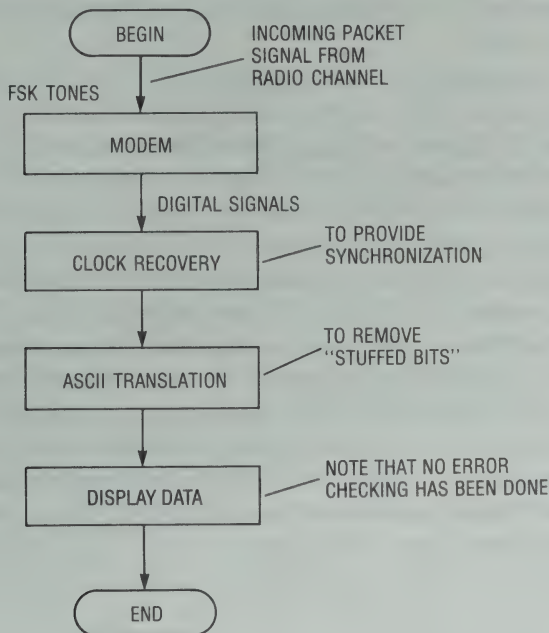
Ever since the early days of Amateur packet radio activity, the personal computer has been used to design and implement packet protocols. Regardless of which computer you may have, there is one piece of external hardware you can't do without. It is still necessary to have a hardware modem of some kind to convert from computer signals to tones and vice versa. Perhaps with computers employing special sound generating chips, the transmit tones can be generated internally. In some cases, hobbyists have had limited success with using the analog-to-digital joystick or paddle ports on their computers to detect received tones, but it's far from the ideal way of doing it.

## Receiving and Displaying Packets

Once we have a modem properly interfaced between the personal computer and the radio equipment, we can begin the task of receiving and sending packet transmissions. Let's begin by simply trying to display any packets we receive. The flow chart in *Figure 8-1* will help you follow the process.

Displaying packets is not all that difficult to accomplish. We begin by converting the received tones into digital signals for your computer. That's the job of the now-familiar modem.

**Figure 8-1. Just presenting incoming packet data on a CRT screen requires the steps shown before the data can be displayed.**



## **NRZI Encoding**

For regular conversations, data is encoded using ASCII, but unfortunately it doesn't get transmitted in the way your computer is accustomed to seeing it. Your computer is normally looking for an asynchronous serial signal, but packet is transmitted using synchronous techniques. In synchronous transmissions, the clock signal is derived at the receiver from signal time transitions contained in the transmission. The time transitions are conveyed between sending and receiving stations by using a type of encoding known as *non-return to zero inverted* (NRZI). The transmitted signal switches tones only when the bits *change* from one to zero or from zero to one. Successive bits of the same value do not produce a change of tone. The receiving station detects the transitions and adjusts its clock timing accordingly.

## **Bit Stuffing**

There are some special instances where NRZI can cause a problem. The start flag, for example, is the special sequence 01111110. If five consecutive ones are detected in outgoing data, a zero is inserted on the sending end and then removed on the receiving end. This forces a tone transition at least once every five bits to maintain synchronization and keeps the receiving station from accidentally interpreting a non-flag signal as a flag sequence. This technique is called *bit stuffing*.

Not only do we have to maintain proper synchronization, but the receiving station also must recognize the start flag and compensate for bit stuffing in order to properly display incoming packets.

## **Displaying**

In summary, to receive and display packets on a personal computer, we must operate the communications port at the proper speed, recover the synchronization signal, interpret the received data, and translate it into standard ASCII before displaying it on the screen.

The degree of difficulty in doing this is roughly equivalent to receiving AMTOR transmissions. Several commercial programs allow for AMTOR operation using the personal computer with no additional hardware except for a simple outboard modem.

When packet is displayed using one of these available programs, probably the first thing you will notice is that each group of plain English characters is preceded by a certain amount of gibberish. That is because each packet contains header information that is not necessarily represented in ASCII form. Your computer will try to interpret it as if it is ASCII and the result is the gibberish.

In addition, to this point, no error checking has been done on the received data. While our simple display system will show the transmitted CRC value, a CRC value has not been calculated for the received data to compare with the transmitted CRC.

We can conclude that the ability to monitor and do a simple display of packet transmissions is probably within the range of most home computers; however, when we start making additional requests of the PC, we can rapidly run into problems. Let's see what some of these are.

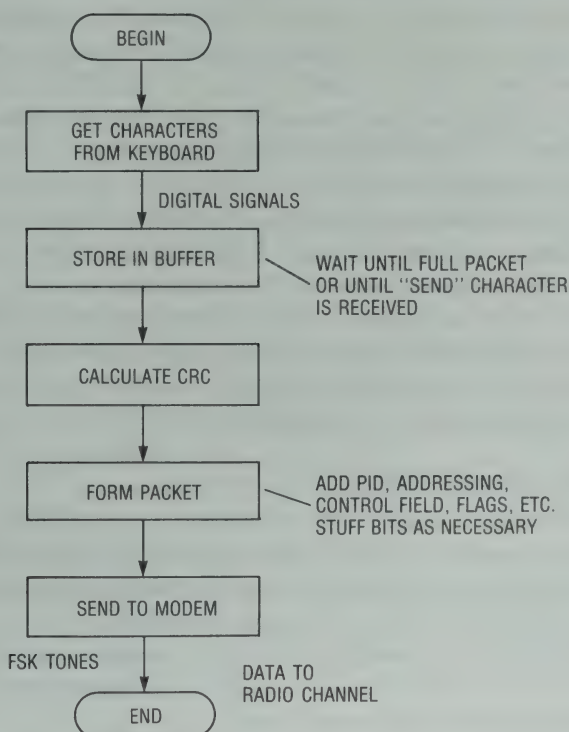
## Transmitting Packets

To transmit packets of information which are recognizable to other stations in the network, we must consider the protocol being used. For Amateurs, AX.25 rules the airwaves. *Figure 8-2* shows the major steps involved in transmitting an Amateur packet signal.

The program in our PC must allow us to generate information and buffer it before transmission so it can be properly formed into packets. Recall from Chapter 4 the basic elements contained in each transmitted packet. We must have a start flag signal, addressing information, protocol identification bits (PIDs), information concerning the type of packet being sent, and other data. The frame check sequence (FCS) also must be calculated and included in the transmitted packet. The NRZI encoding must be programmed into the PC so that it can properly drive the modem.

In a dedicated hardware TNC, we have a special integrated circuit or two that have all of these functions built-in. These specialized chips do not exist in your home personal computer. Through machine language programming, you have to create the equivalent of such circuits using the standard chips available within your PC. This programming requires someone quite knowledgeable about your particular machine; however, it is still within the range of tasks that home PCs can accomplish fairly easily when properly programmed.

**Figure 8-2. Transmitting a packet signal involves a complicated process based on the AX.25 protocol. This is a very simplified flow chart of the steps involved.**





## Putting It Together

If we now take the receive and transmit programs and integrate them into a single software package, we will be able to send and receive packet transmissions. However, we still do not have a fully functional TNC.

For two packet stations to communicate in an error-free fashion, they must not only be using the same format for sending and receiving information, but they also must decide how to handle the packets once they are received.

To take a simple example, the receive station must extract the FCS or CRC value and compare it to the value it calculates for the received packet. If the values compare satisfactorily, the receive station must transmit a properly formatted ACK back to the transmitting station.

What happens if a received packet arrives out of sequence? The program must know how to handle such a situation.

In short, each and every rule contained in the AX.25 protocol document, which consists of dozens of pages, must be properly implemented within the PC. This is a formidable, very detailed programming task!

## Existing Programs

At least two programs have been successful in implementing a packet TNC using a home PC. The first is available commercially for the Radio Shack Models I, III and IV computers. The second is a public domain program for the Commodore 64.

Robert Richardson discusses the techniques he used on the TRS-80 Models I and III in a multi-volume book set titled *Synchronous Packet Radio Using The Software Approach*. He also offers the programs in ready-to-run form. Since the programs have over 5000 lines of assembly language source code, you aren't likely to want to enter them by hand.

A group of German amateurs have placed a program in the public domain that operates on a Commodore 64. While the program is widely available, few individuals have reported success in using it in actual operation. Part of the difficulty may be that the documentation available is written in German. The program also seems to be undergoing continuous changes. Experimenters are sometimes hampered by trying to work with different versions of the software.

There are at least two other developments for the Commodore 64, but neither one has ever become a success. In both cases, the software authors indicate they are having difficulty in successfully merging the transmit and receive packages together. Let's see if we can figure out why.

## Timing Considerations

All operations in packet radio are based on critical timing. Early home computers typically operated with CPU clock speeds of just over 1 MHz. Even before trying to implement a packet program on such a machine, the processor is often stretched to its limits to find enough time to do everything.

In the case of machines that include complex graphics and sound capabilities, much of the processor time is used just keeping the screen information updated and properly addressing the sound chip.

The software-created timing circuits so necessary to proper packet operation function properly only if the CPU in the home computer is available each and every time the program demands access for timing functions. That's asking a lot from a 6502 or 8080 family processor running at 1 to 2 MHz!

### **Lack of Special Features**

With a dedicated outboard TNC, the PC is available to run very sophisticated terminal software which includes some special features, such as capturing messages to a buffer or disk, split-screen operation, and using macros (a single instruction containing or implementing several separate instructions) to simplify repeated keyboard entries. But when your PC is already humming along at top speed just to display packets on the screen and deal with your keyboard input, there's no time left for it to handle such features, even if enough memory is available.

### **TNC Seems to be Better**

Most hobbyists who started into packet radio using the software approach usually switch to an outboard dedicated TNC. In the early days of packet when TNCs weren't available, or cost around \$500 for those available, it made sense to try to do all packet functions in a home computer. However, with the most popular TNCs priced between \$100 and \$200, it makes very little sense to invest half that amount in software alone and still have to build or buy an external modem.

But before you write off using your personal computer as a TNC, there are some other methods that you may want to consider. They are a hybrid between the hardware and software approaches.

### **HYBRID HARDWARE AND SOFTWARE**

In Chapters 6 and 7, we learned about the WØRLI bulletin board system and its early implementation on a surplus Xerox® 820 computer. Because the 820 was such a popular work horse in the early days of packet, it's not too surprising that some work was done to allow it to be used as a TNC itself. Several approaches were tried.

One design actually modified the computer's circuit board to make it more usable for packet; however, the most popular approach involved the use of a so-called daughter board to add additional circuitry for packet operation.

Very simply, the addition consisted mostly of an HDLC chip and an outboard modem. You will sometimes find this board referred to by the name of a frame assembler-disassembler (FAD) board. Not too surprisingly, similar approaches are used in several available commercial units.

### **Multi-Mode Units**

Several manufacturers have been successful in integrating several modes of amateur digital communication into a single software package requiring only an external modem. AEA took this one step further and created a MICROPATCH™ with the software and modem built into a single cartridge that plugs directly into the expansion port on the Commodore 64 computer.

It is proper to point out that in some of the units, full AMTOR operation is often far from satisfactory. Timing problems plague such units, but careful adjustment of the clock frequency in the computer often remedies most problems.

In a further step, a compromise approach created a similar package that also allowed full packet operation. Because so much of the difficulty in properly programming for packet involves implementing the HDLC protocol itself, an outboard HDLC chip was used. With this compromise, the problem is greatly simplified.

AEA chose to do exactly that in the PAKRATT™ (PK-64) unit, which is shown in *Figure 8-3*. A multi-conductor cable connects the PK-64 to the expansion bus on a Commodore 64 or 128 computer. The terminal software used in the PK-64 is largely an updated version of that in the MICROPATCH units. It functions on all digital modes. It is a full-featured package as illustrated by the on-screen menus shown in *Figure 8-4*. One major omission from the PK-64 terminal software is that no provision is made for transferring computer programs. Text files can be sent and received by using the buffer, but program transfer is not possible directly to or from disk. The software does have extensive text editing capabilities that include delete, insert and block moves of data from one buffer to another.

The addition of the HDLC and a well designed modem with optional tuning indicator brings the hardware complement in the Commodore 64 up to the task of effectively working with packet.

**Figure 8-3. The AEA PK-64 is a cross between a hardware and software based TNC.**



*Courtesy of Advanced Electronic Applications*



**Figure 8-4.** The terminal program built-in the PK-64 is extremely versatile and easy to use, as illustrated by the menus shown, but it is limited to text file transfers only.

```

                29-OCT-85 01:00:59
PAKRATT tm 30.SEP 85
Copyright 1985 by AEA

SELECT:

P. PACKET
A. AMTOR
R. RTTY: BAUDOT
I. ASCII
W. MORSE
K. CALIBRATE
L. LOAD
B. BROWSE
E. EDIT
M. MOVE
S. SAVE
T. SET TIME
C. SET COLOR
D. DISK
O. BACK TO BASIC

```

```

                29-OCT-85 01:01:59
AUTO-CR-T 0 MAXFRAME 4 RTTY:
AUTO-CR-R 80 MFILT $0000 AUTO-CR ON
AUTO-LF-T OFF MFILT $0000 AUTO-LF ON
AUTO-LF-R OFF MONITOR 2 ARQTM 45
AX25L2V2 OFF MONCON OFF QRL 160
AXDELAY 0 MONDIGI OFF SELCALL KKBG
AXHANG 0 MONREJ OFF USOS ON
BAND VHF MONRPT OFF WORDOUT ON
BEACON EV 0 MFROM ALL XMITREV OFF
CHECK 30 MTO NONE
CONMSG OFF MONSTAMP OFF
CONMODE CONV MYCALL KB76
CONOK 10 PACLEN 128
CONSTAMP OFF PACTIM AF 4
CPACTIME OFF PASSALL OFF
DAYSTAMP OFF PRINTER 1
DIGIPEAT 2 PRNCMD 0
DWAIT 2 RESPTIME 12
ECHO ON RETRY 10
FRACK 3 SQUELCH NEG
FULLDUP OFF TXDELAY 4
HARDTIME ON UNPROTO CQ
HEADERLN ON WRAP ON
LCOK ON XMITOK ON

```

```

                29-OCT-85 01:02:28
BTEXT: AEA PK-64 Answering System active.
CTEXT: AEA PK-64 Auto-Answer ---; Please leave message, then disconnect.
DISCONNECTED
UNPROTO: CQ
MON FROM: ALL
MON TO: NONE

```

*Courtesy of Advanced Electronic Applications*

## Why Commodore 64

Why the Commodore 64 computer and not others you may wonder. First, the Commodore 64 is designed with an open architecture which allows easy addition of hardware and software. Second, at one point in Amateur history, over 70 percent of Amateurs who owned a computer owned one of the Commodore machines. The manufacturers simply addressed the marketplace as it then existed.

## Plug-In Cards for the PC

Perhaps one of the most likely areas for development in the near future are TNCs on a plug-in card for the IBM PC<sup>TM</sup> and compatibles. Just as a regular modem card can be plugged into an expansion slot in the PC, a packet modem card can be plugged into the same type of slot.

A Canadian group, The Hamilton Area Packet Network, introduced such a card for the PC recently. Perhaps the limited response to the project is a result of the relatively low cost for external units and the difficulty in buying merchandise across the border. At least one U.S. supplier, PacComm, has announced a similar board known as the PC-100<sup>TM</sup>.

## A LOOK AHEAD

The speed and capabilities of the home PC are increasing rapidly. As a result, it is quite possible that a software intensive approach to packet transmission and reception will be practical in the years ahead. In your author's opinion, as the value of packet transmission becomes more apparent to both the hobbyist and business person, we will see more plug-in cards for PC-type machines. They can be addressed by software written to use them specifically for a number of different packet protocols, including AX.25.

It is surprising that there is not already a true packet radio; that is, a radio transceiver that has the packet TNC or multi-mode modem as an integral part of the unit. Such a radio would likely have a RS-232 connection on the back so that only a terminal and an antenna would be required for a complete data station.

We are probably not too many years away from using packet techniques for almost all of our data communications, whether they are over Amateur Radio frequencies or simply over a telephone line between two hobbyists. In the long run, we may find that packet protocol of some sort comes as a built-in feature in most PCs.

## SUMMARY

Unless you are a serious programmer or experimenter, you will probably want to choose an outboard TNC hardware unit for packet operation. However, it's good to have an understanding of how packet communications can be implemented on a PC, because this knowledge will also help you to understand how packet operations are programmed in external units as well.

# Packet Radio Accessories, Innovations and Organizations

While the main components of an amateur packet station consist of a personal computer or terminal, a TNC or multi-mode radio modem, and a radio transceiver and antenna, there will always be room for add-on accessories. Packet is growing in many ways and this means the introduction of new kinds of hardware and software with which you should become familiar.

## TERMINAL EMULATION PROGRAMS

One area of digital communications that has been, and is, attractive to Amateurs with an entrepreneurial spirit is the design of terminal software especially for packet operation. It is important to emphasize once again that virtually any terminal program you use with a regular telephone modem will work just fine with a packet TNC. There are some unscrupulous people who would have you believe that you can't live without a special packet radio terminal program for your computer. That just isn't true. On the other hand, once you use a communications program designed especially for packet radio, you will probably become hooked on it. Interestingly, one of the first, and still one of the best, commercial packages available is designed for a machine that you might not expect in a ham shack.

### For the Mac

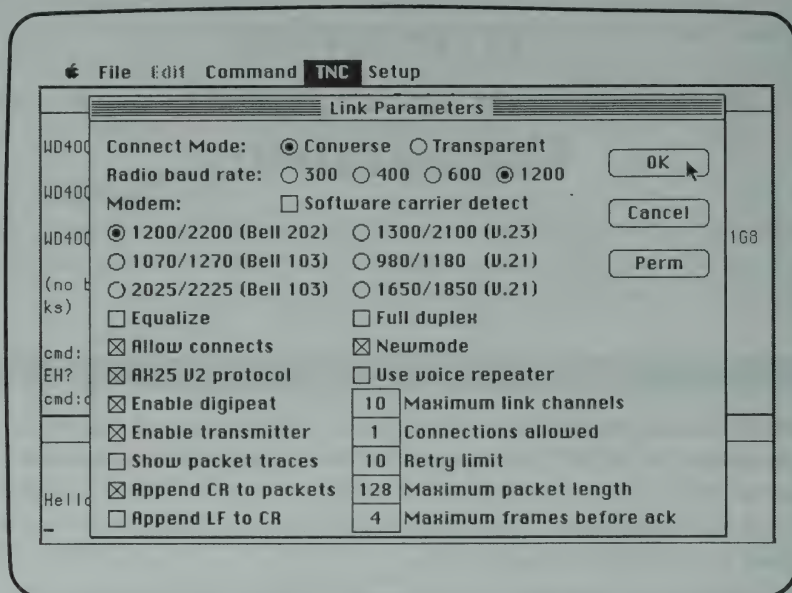
If you check the spelling of MacPacket™ closely, you might guess that this is a special packet program for the Macintosh® computer rather than a small, new type of fast-food sandwich.

Since its introduction, the Macintosh computer has been hailed as the computer for people who hate computers. The MacPacket program from Brincomm Technology follows this lead and brings ease of operation to Amateur Radio for those with a Mac in their shack.

Utilizing the windowing feature of the Macintosh, split-screen operation is easily implemented. *Figure 9-1* shows just a few of MacPacket's features. Commonly used connect paths are stored for you and can be retrieved through a menu. Up to 100 paths can be stored in the program.



**Figure 9-1. A sample screen from the MacPacket terminal program.**



*Courtesy of Brincomm Technology*

The TNC command set is available as a menu, making the instruction book almost unnecessary. Because of slightly differing command structures, separate versions of the program are available for TAPR and Kantronics type units.

Messages are easily stored and retrieved. Along with its many other features, this makes MacPacket a truly state-of-the-art terminal program for packet radio.

## For the Commodore

One of the first terminal programs written specifically for packet is offered by the Texas Packet Radio Society (TPRS) for the Commodore 64 and 128 computers. It is called TNC-64. It's a full-featured program designed for packet operation. With some careful programming and what seems like a bit of magic, the TPRS package software allows a full 50K of buffer storage. The program also allows the buffer to be automatically dumped to a disk when it becomes full, allowing large amounts of information to be captured even when you are away from the terminal.

The TPRS package is a bit sluggish for fast typists, but the problem is not noticeable to most hams who hunt and peck or type at slower speeds. Profits from the sale of this package are used for research and development of the Texas packet radio network, known as TexNet.

## For the TRS-80

Computer hobbyists who have the Radio Shack TRS-80 Model I, III and IV machines may be interested in an offering from the Martin Company. Their packet terminal programs offer split screen operation, ten buffers, disk save, file transfer, printer output and a text editor.

## For the PC

One of the first packet terminal programs for IBM PC type machines is manufactured by Kalt and Associates. They call it Pak-Comm™ and it has many of the same features already discussed in other programs.

Early efforts by some of the amateur equipment manufacturers were little more than bare bones terminal emulation programs that simply were not worth the purchase cost. Many public domain programs offered more features. That's no longer the case.

With the universal or multi-mode unit becoming very popular, it is now possible to offer a single program that can be used with most TNCs or radio modems. The number of entries into this area is growing almost daily. AEA, MFJ and Kantronics offer full-featured programs for the IBM PC and Commodore. Generally speaking these programs offer many of the features found in earlier dedicated hardware/software combinations.

The IBM version of the AEA program, called the PC PAKRATT™, offers a friendly help menu, a 64K buffer for incoming data, and a full-featured text editor. As you can see in *Figure 9-2*, it is another full-featured terminal program especially written for packet and other digital operations. A disk utility section allows you to view the directory, to perform file transfers and store received data.

**Figure 9-2. The AEA PC Pakratt program is a special terminal software package for use with the IBM PC or PC compatibles.**

PC-PAKRATT c 1987 by AEA		MAIN MENU		21-Sep-87 15:53	
SELECT MODE			DOS OPERATIONS		
F3 AMTOR	F2 Packet	T set Time/date	C Copy file		
F4 Baudot	F4 Baudot	D list Directory	R Rename file		
F5 ASCII	F6 Morse	P Print file	S eraSe file		
F7 FAX	F8 Dumb Terminal				
MISCELLANEOUS					
B Browse	E Edit	L Load	F9 define softkey		
Q Quit program	V Save	X eXit program			
F1 User2window1			F2 User window		
For help type F1					

*Courtesy of Advanced Electronic Applications*

## TUNING INDICATORS

If low band packet operation is what interests you, a tuning indicator is almost a necessity. If you own a TNC 2 or other unit designed primarily for VHF operation where tuning is not required, an add-on tuning indicator will be one of the best investments you can make.

If you are interested in just adding a tuning indicator, MFJ offers an excellent choice with their MFJ-1273. It uses the standard modem connection found on TNC 1 and 2 type units.

You can add a tuning indicator and improve the performance of your TNC on HF as well with the PM-1™ Packet Modem from AEA, shown in *Figure 9-3*. It requires no internal modifications to either your TNC or transceiver. It employs independent dual channel filtering with AM detection for maximum sensitivity and selectivity when HF conditions are less than optimum. A switch on the PM-1 allows you to switch easily between HF and VHF operation. Connections are provided for two different radios to make the swap even easier.

If you prefer to build your own, you may find the article in the March 1983 issue of 73 Magazine about a tuning indicator designed by Jon Langner, WB2OSZ, of interest. The same tuning indicator is also described in the October 1985 issue of TAPR's *Packet Status Register*. The same issue describes a somewhat different tuning indicator designed by Dan Vester, KE7CZ, for the TNC 1 and 2.

**Figure 9-3. An external modem like the PM-1 can improve packet performance, particularly on HF.**



*Courtesy of Advanced Electronic Applications*

## AUDIBLE ALARMS

The PK-64 unit contains a feature that some people find amusing, if not desirable. Leave it to an enterprising amateur to take a good idea and help spread it to others!

When selected from the parameter menu, the PK-64 utilizes the sound chip in the Commodore 64 to sound a connect siren whenever your station receives a connection from another station. It's enough to make you think the world has come to an end if you have the volume set too high!

The Maxtec company offers a device called the Kon-D-Kon™ (for Konnect-Dis-Konnect), designed for the TNC 1 series units. It provides both a beep tone and a lamp indication when someone connects to your station. Such a unit can be used in a very important way. It could be used to signal a handicapped amateur when a connection is established without requiring the CRT to be on all the time.



## Interface Box and Monitor

Many new packet enthusiasts discover that interfacing a TNC to the radio equipment could be considerably easier than it is in some situations.

Electron Processing sells a popular item called the Brapper Box that works well as a TNC to transceiver interface. Several models are available so that the unit can be plugged in directly to most popular TNCs.

Two internal amplifiers and three front panel gain controls give you complete control over audio levels. You can monitor the incoming packet audio using an internal amplifier to drive a speaker, or turn the volume down to eliminate the sometimes annoying “brapp” sound that packet radio makes. Most of the popular walkie-talkies can be keyed directly with this interface. The unit is simplicity itself and makes interconnecting the hardware for packet a breeze.

## SOFTWARE UPGRADES

If you buy your TNC used or at a fire sale, it would be worth your while to check to see what version of the software it contains. All popular TNCs have gone through a number of subtle and not-so-subtle software changes. Some pretty serious flaws are corrected with some versions while new features are added with others. Check with the manufacturer of your unit for details on obtaining upgraded software.

If you have a TNC 1 or licensed clone you may be particularly interested in the software available from Ron Raikes, WA8DED. As mentioned earlier, it gives the TNC 1 many of the newer features found in current software for the TNC 2. Ron's software is unique in that it is fully copyrighted and cannot be used or reproduced for commercial purposes, but the source code is available for no charge to individuals for their personal use. It uses a somewhat different approach to the command mode. It is never necessary to change modes to give commands. An escape character at the beginning of a line signals that a command will follow. Otherwise, data is assumed for every line.

## VIDEO TAPES

If you would like to *see* how packet radio works, or if you would like to show others how it works, several video tapes are available at very reasonable cost.

Perhaps the introduction to packet radio produced by TAPR and starring “Packet Pete” Eaton, WB9FLW, is the best available. It is professionally produced, though Pete's style comes across as much warmer in person than it does on the tape. The graphics that support Pete's explanations are excellent. Contact TAPR directly for information on obtaining a copy.

Phil Anderson, WØXI, the president of Kantronics, hosts an introductory tape on packet that makes a good radio club program. The tape is available for loan directly from Kantronics.

## NETWORK NODE CONTROLLER

From reading about the Amateur packet network, you know that there are many frontiers left to be explored. As Amateur networking progresses, there is a need for more sophisticated control hardware.

A group of dedicated TAPR volunteers is currently working on the next generation of hardware known as a network node controller (NNC). It is a very sophisticated piece of hardware that can control four HDLC (packet) ports, two asynchronous ports, up to a half-megabyte of memory, a parallel port and a real-time clock. It is based on the 64180 processor, which is similar to the Z-80.

As this is being written, the hardware itself exists and is operational in a workshop environment. In the near future, as amateurs begin to agree on higher levels of networking, software can be implemented to control a number of packet channels. At this time, there is no available commercial implementation of the NNC.

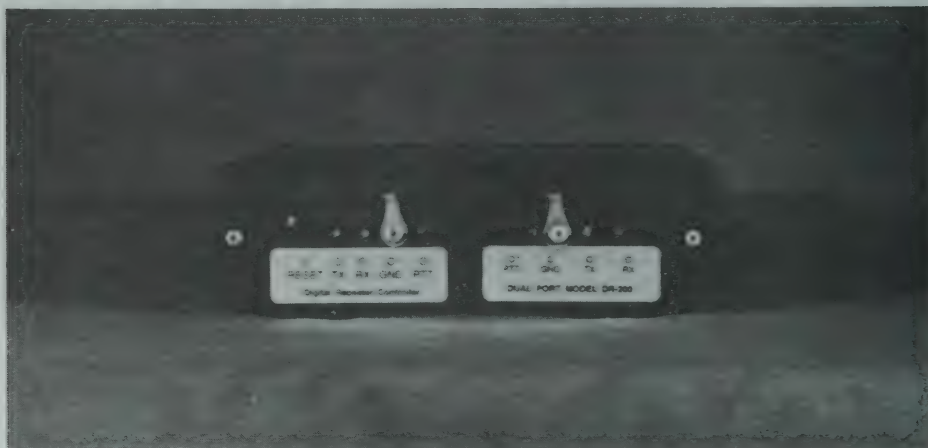
## DUAL-PORT TNC

The advantages of dual-port TNCs for simple networking have already been discussed. Recall that a dual-port TNC can be used to bridge two different packet channels together or pass traffic from one level of networking to another. While the modifications required to transform a standard single-port TNC into a dual-port machine are not beyond the ability of many amateurs, a commercial implementation of the dual-port hardware by PacComm, known as the DR-200™, has helped to spur advances in the field of amateur packet networking. In *Figure 9-4*, notice that the DR-200 doesn't look much different than a standard TNC. A single-port unit, called the DR-100™, designed strictly for dedicated digipeater operation, can be upgraded to a DR-200 when required.

## PACKET RADIOS

While the dream of a true self-contained packet radio seems to be a year or two away, we are getting closer with the announcement by AEA during 1987 of the RFM-220™ Radio Modem. It is shown in *Figure 9-5*. This unit combines a full-featured, digitally-tuned, 220 MHz FM transceiver with a 19,200 bauds packet modem. You still have to supply a separate TNC and terminal.

**Figure 9-4. The PacComm DR-200 is a dual port packet controller.**



*Courtesy of PacComm*

**Figure 9-5.** AEA has introduced an integrated high-speed packet modem and radio transceiver especially designed for networking operations.



*Courtesy of Advanced Electronics Applications*

One of the difficulties in developing high-speed packet networks is that most transceivers are not well suited to the rapid switching times associated with high-speed data transmission. The RFM-220 optimizes the radio to the modem for a single integrated unit.

Power output is fully adjustable from 1 to 25 watts. The unit is CPU controlled and has an input for computer control via RS-232 signal levels.

Other manufacturers have shown modem and radio combinations capable of at least 9600 bauds, but the RFM-220 represents a real breakthrough.

## **SPECIALIZED MODEMS**

If you are interested in experimenting with high speed digital transmissions, you will have to add an external modem to your TNC. Most standard units only include the capability to send and receive either 300 or 1200 bauds packet signals.

At this time, commercial manufacturers are just beginning to enter the area of high-speed modems. Special problems are encountered with higher speeds that necessitate integrating the modem into the radio to make the system work properly. AEA has demonstrated the advantage of the combination with the RFM-220.

A different type of modem is required if packet radio via Amateur satellites interests you. The reasons are explained in Chapter 10, which is devoted entirely to satellite operation.

## **2400 Bauds**

If you have applications in mind that can use extra speed *now*, there is a unit available on the market today that will help to increase your system's throughput significantly.

Utilizing techniques similar to high-speed telephone modems, the Kantronics 2400 bauds TNC doubles the usual channel speed for packet transmissions.



There are no inherent problems in the system, but it has not yet caught the imagination of Amateur Radio operators. It is the only commercial 2400 bauds unit on the market. It can be commanded to operate at the traditional 1200 bauds rate so it is compatible with existing TNCs. If you invest in one, your biggest problem will probably be finding someone with similar 2400 bauds capabilities.

Incidentally, doubling the channel baud rate does not double the throughput of packet transmissions. Due to the overhead inherent in packet transmissions the result will be somewhat less than double the 1200 bauds speed. Under conditions approaching optimum, that is, no digipeating and no competition for the radio channel, the greatest increases will be realized. Of course, this is true at any baud rate.

There's little doubt that all of us will eventually convert to higher speed operation, but that day hasn't come yet.

There are other individual efforts aimed at sending packet at both 4800 and 9600 bauds, but the speeds we have discussed here are the only ones that have seen much activity.

## PORTABLE PACKET

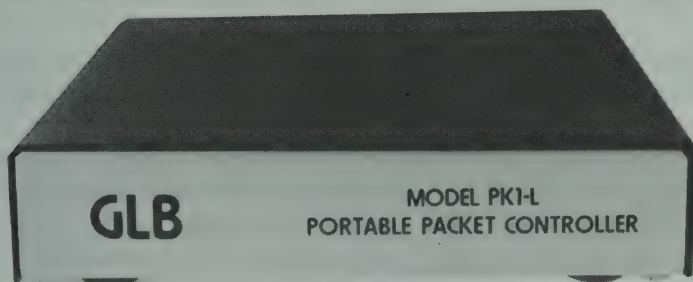
TNCs keep getting smaller and so do laptop computers. The Radio Shack models 100, 102 and the model 200, shown in *Figure 9-6*, have long been favorites with writers and other people on the go. In the last few years, they have been discovered by Amateur Radio packet enthusiasts as excellent terminals for portable packet operations. There's even a small packet bulletin board system that will run on them! Your author has used one for demonstrations of packet radio to computer clubs and in college lectures on communications. All that's required is the laptop, a TNC, and an FM transceiver link to communicate with other Amateur Radio operators.

**Figure 9-6.** With a portable computer like the Radio Shack 200, packet operations can take place almost anywhere.



Several companies offer TNCs designed for low power consumption, making them likely candidates for portable operation. One such unit by GLB is shown in *Figure 9-7*. Coupled with an inexpensive walkie-talkie FM transceiver, a complete packet station will fit in your brief case.

**Figure 9-7. A low power GLB PK1-L™ also is required so that packet operation can take place almost anywhere.**



*Courtesy of GLB Electronics, Inc.*

## ORGANIZATIONS

While reading about packet radio is a worthwhile endeavor, there's nothing like seeing it demonstrated in person. Around the country there are thousands of radio clubs. Some of them even specialize in packet radio or have a sub-group for this aspect of the hobby.

The best way to find one of these clubs is to contact the American Radio Relay League, 225 Main Street, Newington, CT 06111, telephone (203) 666-1541.

## AMRAD

In the United States, there are two organizations that served as the granddaddies of almost all packet activity. The first is the Amateur Radio Research and Development Corporation (AMRAD). Traditionally, this organization has been active in development of special communications modes. For example, they have done a lot of work on developing Teletype Devices for the Deaf (TDD) for amateurs and other people with hearing problems.

In the early days of packet radio, much of the U.S. packet activity was centered in the Washington, D.C. area where AMRAD has its headquarters. Most early work involved using Vancouver packet boards and protocol. Particularly in early packet literature, you'll find many references to AMRAD and their work with the Xerox 820 computer for packet operations.

Like most volunteer organizations, AMRAD suffers a rise and fall in activity levels as members come and go. Membership is open to amateurs worldwide, though you are likely to derive the greatest benefit from membership if you are in the D.C. area and can attend the meetings and special presentations that AMRAD sponsors.

## TAPR

As packet radio grew and people moved around in their jobs, another organization was formed in the Tucson, Arizona area to develop packet radio techniques on a not-for-profit basis. Even though the group is headquartered in Arizona, it is truly an international organization with a board of directors from all corners of North America.

TAPR is largely responsible for packet radio being what it is today. They are the designers of the TNC 1 and TNC 2. They were one of the major contributors to the AX.25 level two protocol.

Membership is open to anyone interested in furthering packet radio. Almost since the beginning, the group has published *The Packet Status Register* (PSR). For about a year, PSR was incorporated into another independent packet publication produced by the Florida packet group. This publication, *Packet Radio Magazine*, ceased publication during 1987 and TAPR is now producing PSR again on a quarterly basis. Under the editorship of Scott Loftness, W3VS, PSR has returned as a valuable source for packet information.

## HamNet

If you have a computer and a telephone modem, there is someplace you can go for help and information on packet radio before you invest in any additional equipment. HamNet is a special interest group (SIG) that is part of the CompuServe Information System. It is one of the oldest forums on the system and is dedicated exclusively to Amateur Radio and shortwave listening.

One of the most popular topic areas within HamNet is section nine, which is devoted entirely to discussion of packet radio topics. On the public message board, you'll find others willing to help with everything from your most basic questions to those about new and innovative technology.

Here you are likely to find some of the most prominent Amateurs involved in digital communications. HamNet also serves as an electronic connection to TAPR Headquarters. There are regular check-ins from other national organizations and manufacturers of Amateur digital equipment. HamNet is popular with Amateurs around the world, boasting regular participation by Amateurs in Sweden, Germany, Japan and many other foreign countries.

A treasure chest of programs and information files can be found in the data libraries. The programs range from simple packet terminal software to very complex packet bulletin board systems. *Figure 9-8* shows just a very small portion of the packet data library directory. The only cost involved for any of the programs or participation on the message board are the normal CompuServe connect charges. In fact, if you have a program or long file to share with others, your time spent uploading to the data libraries is now *free* on CompuServe!



**Figure 9-8. This is just a partial listing of the programs and files available about packet on CompuServe's HamNet forum.**

File Name	Upload Date	Size
ALASKA.MAP	25-Nov-87	3584
AX25V3.CMT	07-Nov-87	19795
AX25.NKF	01-Nov-87	162944
COSI10.DOC	25-Oct-87	78367
CPBBS.DOC	01-Oct-87	18266
MBL320.ARC/binary	24-Sep-87	330173
MFJUPD.115	06-Sep-87	17168
MODEM.56K	30-Aug-87	88832
MONAX2.ARC/binary	22-Jul-87	7552
PK232N.CMD	17-Jun-87	7386
PK232.INF	20-Apr-87	13494
RLI32S.ARC/binary	10-Apr-87	17269
TERM.EXE/binary	22-Feb-87	6340
TEXNET.DOC	08-Sep-87	4352
TPRS03.01	15-Mar-87	17665
X820V1.1	21-Apr-87	4351

*Courtesy of CompuServe Incorporated.*

If you are not already a CompuServe subscriber, you can obtain a universal sign up kit from your local Radio Shack store or dealer. Ask for item 26-2224.

Once you have your CompuServe ID, you access HamNet by typing **GO HAMNET** at just about any prompt in the system.

## PUBLICATIONS

If you are interested in reading and learning more about packet radio, there are several periodicals you may find of interest.

The major Amateur Radio magazines, *QST*, *CQ*, *73* and *Ham Radio* frequently include articles on packet radio techniques, as well as reviews of popular digital hardware and software. All of them at some point in the last three years have published a series of articles on packet radio, or devoted special issues to the subject. Only *73* has chosen to devote a regular column to the subject. A somewhat lesser circulated publication called *World Radio* includes a monthly column called "The Digital Bus" which covers all aspects of digital communications.

It may be difficult to find copies of these publications at your local newsstand. You'll probably have much better luck locating them at your local electronics dealer, particularly those that sell Amateur Radio equipment.

Your best bet for regular, late-breaking news about packet radio is one of the several specialty newsletters published on the subject. In addition to the TAPR *Packet Status Register* already mentioned, the American Radio Relay League publishes the *Gateway* newsletter, edited by Stan Horzepa, W1LOU. Stan is also the columnist who writes the "ONLINE" column which appears sporadically in *QST* that deals with digital communications modes.

Another monthly publication, called *Spec-Comm*, (short for specialized communications), includes information on digital modes.

Other publications have come and gone over the past few years. Several of the larger local and regional packet radio clubs publish very fine newsletters as well. Once you are active in packet radio, don't overlook the amazing amount of information that you will find on your local packet bulletin board system.

## SUMMARY

As packet radio continues to grow in popularity, more accessories will become available. They will allow owners of existing hardware to enjoy new features and expand the versatility of all packet systems.

Perhaps the most important growth will come in packet radio clubs and organizations. Nothing can beat first-hand sharing of knowledge and experience. Local clubs in particular are a good way to learn about packet radio. Who knows, you might even get to see a demonstration of using Amateur Radio satellites to relay packet signals across the country and around the world. That's the subject of our final chapter.

# Packet Satellite Operation

One area of Amateur Radio that is very exciting is the involvement of Amateurs in satellite communications. Now that digital computer communications are within the reach of most hobbyists, the marriage of packet radio and satellite operation is particularly interesting.

Amateur Radio interest in communications satellites goes all the way back to the early 1960s. It was during this period of early space exploration that Amateurs designed and built the first Orbiting Satellite Carrying Amateur Radio (OSCAR).

## THE OSCAR SATELLITES

The first OSCAR was very simple. The entire satellite was about the size of a bread box with a single rigid, wire antenna about 19 inches long. *Figure 10-1* puts the size of the unit in perspective. The satellite transmitted a Morse code signal on the 2 meter band.

Amateur satellites are placed in orbit on a "space available basis." Particularly in the early days of the space program, OSCAR flew as "ballast" for military payloads. It was always considered expendable.

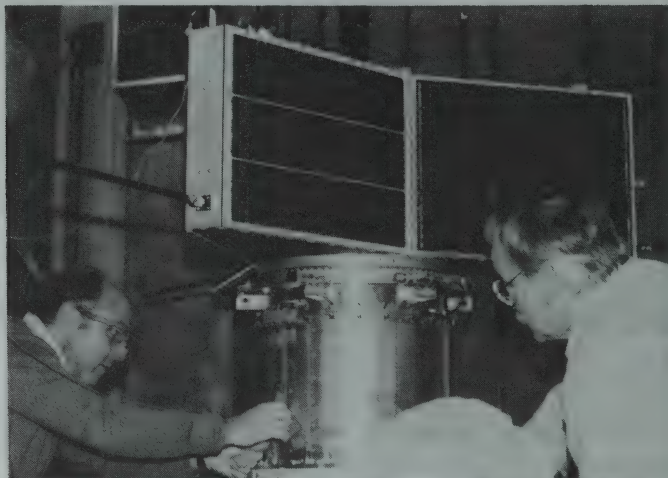
The only telemetry it carried was hooked up in such a way that the speed of the Morse code varied as conditions on the spacecraft changed. The on-board batteries limited operation to only a few weeks.

## Two Way Communications

After several satellites had been placed in orbit and Amateurs had the chance to attain the sophistication necessary to properly track a satellite moving at hundreds of miles per minute, OSCAR III, the first OSCAR capable of relaying communications, was placed in orbit during March of 1965. The power demands were quite high, but during the short period the satellite was active, two-way communications took place between Amateurs around the world, including a contact between an Amateur in the Soviet Union and one in the United States that was relayed by the satellite.



**Figure 10-1. AMSAT OSCAR 13 being fitted with strain gauges prior to vibration testing. AO-13 used the RUDAK digital communication system.**



*Courtesy of AMSAT® AMSAT Photo by Dick Daniels, W4PUJ*

## A New Age

During the 1970s, Amateurs enjoyed the use of several Amateur satellites. Each of them was placed in a low earth orbit in such a way that the satellites were accessible from just about any point on Earth at least twice each day.

OSCAR 6, and later OSCAR 7, carried a *transponder* that relayed signals sent into space, or *uplink*, on the 2 meter band and translated them into an output, or *downlink*, on the 10 meter band. A transponder can be thought of as a very sophisticated repeater system. A repeater "listens" to a single frequency and retransmits the received signal on another frequency. In contrast, a transponder rebroadcasts a *narrow range* of frequencies. The circuitry aboard OSCAR 6 and 7 allowed any type of transmission to be relayed, though narrow bandwidth modes were encouraged in order to allow the maximum number of Amateurs to use the system at the same time. The transponder aboard OSCAR 6 worked particularly well.

OSCAR 7 carried additional circuitry that allowed a 432 MHz signal from the ground to be relayed on the 2 meter band (144 MHz). This unit worked extremely well, making contacts from the midwestern United States to central Europe very common.

Although packet radio didn't exist yet, Amateurs were already beginning to experiment with digital transmissions using the spacecraft. In fact, many hams experienced their first digital communications from space by monitoring the five-level teleprinter code used to send dozens of channels of spacecraft telemetry back to Earth. Amateur communications had come a long way since OSCAR I.

## Learning from Experience

From these early experiences with digital transmissions from the space vehicle, hams learned about the many problems inherent in trying to decode data, especially when sent using traditional frequency-shift-key-keying techniques.

With the coming of the space shuttle, Amateurs anticipated additional access to space. Unfortunately, as budgets were cut and as commercial users became quite willing to pay handsomely to have their satellites placed in orbit, hams found themselves with even less access than before.

Several disasters struck the Amateur satellite program. One satellite was lost when its launch vehicle had to be destroyed. While OSCAR 8 was usable, results were far from what was expected.

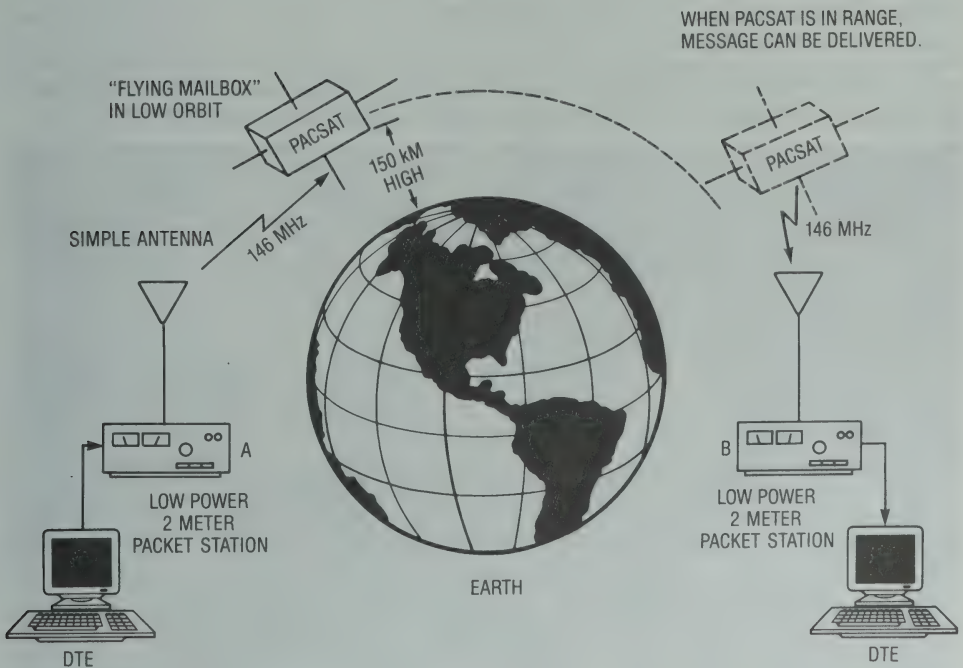
In the meantime, Soviet Amateurs also began constructing similar satellites called *Radio Sputniks* or RS satellites. They usually functioned like OSCAR 6 with similar orbits and capabilities.

## PACSAT

While Amateurs were disappointed that the promise of more sophisticated communications packages would still be years away, dedicated enthusiasts proposed a bold new experiment specifically aimed at making low-cost digital access to space a reality. They called it PACSAT for Packet Satellite.

Amateurs had already begun to experiment with terrestrial packet radio. Its relatively high speed, error-free characteristics made experimenters wonder if it might not be well suited for space communications. The operation of PACSAT, as originally envisaged, is illustrated in *Figure 10-2*.

**Figure 10-2. This is how the proposed PACSAT system would work.**



A relatively simple satellite was to be equipped with a VHF transmitter and receiver, a packet controller, and a store-and-forward type bulletin board system containing a megabyte of storage space.

The satellite was to be deliberately placed into very low orbit. While that would limit the amount of access time, it would help to ensure very strong signals when the satellite was in range. Very simple, non-directional antennas would be used along with low power (10 watt) transceivers.

A ground station wishing to send a message to another station would load the message into his or her computer ahead of the expected arrival time for the satellite. As the satellite came into range, the message would be automatically transmitted to the on-board bulletin board system and stored.

Later, when the intended receiving station came into range, the station would query the satellite's BBS for any messages addressed to that station. It would be easy to automate the complete process.

### Scuttled Shuttle

The visionaries of PACSAT had hoped that the space shuttle could be used to launch a series of PACSAT packages using Get Away Specials, or GAS cans, as they are sometimes called. GAS cans allow small experimental packages to be carried into space aboard the shuttle at a very reasonable cost. *Figure 10-3* shows a GAS can experiment ready for flight developed in Utah by Weber State College and Utah State University. The PACSAT was to be launched by releasing it from the shuttle in much the same way large commercial and military satellites are launched. In the case of PACSAT, the procedure was to be much simpler and no booster rocket was necessary to send the satellite into a high orbit.

**Figure 10-3. NUSAT I satellites were housed in Get-Away-Specials cans to allow inexpensive access to space for projects like PACSAT.**



*Courtesy of Weber State College*



Plans for an on-board shuttle packet experiment were just about to become reality when the Challenger disaster struck the space community. As you can imagine, the Challenger explosion was a severe setback to the PACSAT program.

## The Future of PACSAT

But progress is now under way again. Even as this book was being prepared, funding was approved to build the first PACSAT hardware. It came about because Amateurs have long been involved in public service activities and the use of packet radio satellites in this area was proposed.

The idea of a simple, low-cost message system has an appeal especially for remote areas of third-world countries. Packet satellite Amateur Radio was such a system. The PACSAT idea was presented to Volunteers In Technical Assistance (VITA) as a possible solution to communications problems in these areas. It is through this involvement that PACSAT has finally been funded.

These satellites will not operate on Amateur frequencies nor be available to Amateur packet operators, even though many of the volunteers involved in this project are Amateur packet enthusiasts themselves. It is hoped that by piggybacking production of dedicated ham PACSATs on the VITA project, it will be possible to find the funding and launch assistance needed to make the Amateur packet communications dream become a reality.

## UOSAT/OSCAR 11

The first opportunity amateurs had to try the PACSAT concept occurred when a satellite built at the University of Surrey was successfully launched. Rather than being mainly a communications satellite, UOSAT is designed to be a highly flexible, ground-controlled experimentation package. It has a number of capabilities including the ability to upload programming instructions from Earth that allow the bird to broadcast bulletin transmissions in plain speech using a voice synthesizer. It also has the ability to do visual imaging from space.

Because the circuitry aboard UOSAT is basically a computer in the sky, it can be configured in any way the ground programmers see fit within the limitations of the space hardware. As a result, a digital communications experiment has been tried which emulates the PACSAT techniques. While the experiment is not open to the Amateur community as a whole, those involved report good results.

## AMATEUR RADIO IN THE US SPACE PROGRAM

### Voice

As you can see, Amateur Radio in space is nothing new. It should not come as a surprise, then, to learn that several members of the astronaut corps are active Amateurs themselves. The first ham to receive permission to operate from the space shuttle is Owen Garriott, W5LFL. Owen is shown operating his station in *Figure 10-4*. He used a modified commercial low power hand-held FM transceiver and a simple antenna placed in the window of the shuttle to make dozens of voice contacts with fellow hams on the 2 meter band.

**Figure 10-4.** With a space-hardened version of a walkie-talkie, Astronaut Owen Garriott, W5LFL, was the first amateur radio operator to make contacts from the space shuttle with hams on Earth.



*Courtesy of NASA LBJ Space Center*

## Pictures

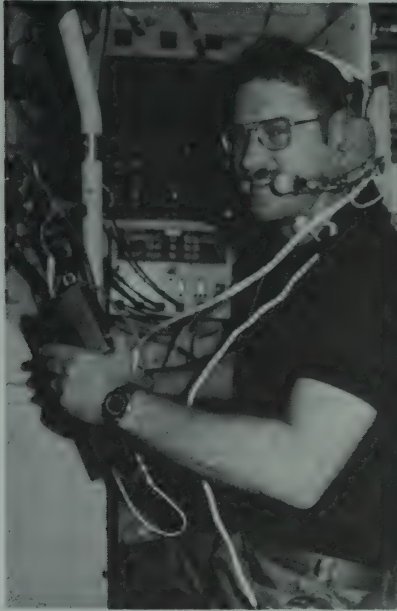
Later, Astronaut Tony England WØORE broadcast not only voice transmissions from space, but also sent live slow-scan television pictures back to Amateurs around the world. The experiment even allowed NASA engineers to send some pictures to the shuttle crew that helped solve a difficult problem. It seems that while provision has long been made for receiving pictures from the shuttle, it had never been equipped to receive pictures until Astronaut England's Amateur equipment was placed on-board! Tony's station is shown in *Figure 10-5a and b*.

## Packet

With the success of several Amateur experiments, packet enthusiasts successfully petitioned NASA to allow a packet experimental package to be placed aboard the shuttle. Officially the project was known as Shuttle Amateur Radio Experiment number 2 (SAREX 2). A NASA astronomer, Doctor Tom Clark, W3IWI and other dedicated hams worked on a short time table in order to have a space hardened version of the software and hardware ready to fly aboard the shuttle in the spring of 1986.



**Figure 10-5. Tony England, WØORE, transmitted and received pictures while in space using Amateur radio.**



**a. Voice**



**b. TV**

*Courtesy of NASA LBJ Space Center*

Due to the many demands on the time of the shuttle crew, the previous hams in space had not gotten to spend as much time operating as they would have liked. The SAREX 2 designers created software that automatically recognized ground station connect requests and then issued a unique serial number to that station to confirm the contact with the shuttle! Up to nine different stations could be connected with the shuttle at the same time. The beacon would be used to show what stations have been recently heard aboard the shuttle. The robot idea was inspired by a similar Morse code unit flown on several Soviet RS satellites.

The SAREX 2 package was flown aboard a conventional aircraft over one weekend to test its effectiveness when confronted with hundreds of simultaneous packet transmissions from the ground. While some problems arose, the experiment was quite successful. Unfortunately, neither SAREX 2 nor any other experiment has flown since the Challenger crew was lost on January 28, 1986.

## **FUJI/F0-12**

Amateur Radio's involvement in space has always had an international flavor to it. While much of the initial work in getting OSCAR launched was done by groups such as Project OSCAR and the Radio Amateur Satellite Corporation (AMSAT), Amateurs from around the world have helped to design and build most of the OSCAR series of satellites. Among the nations who have been actively involved are Australia, Japan, West Germany and Canada, with support from more than a dozen additional countries.



In early August of 1986, Japanese Amateurs successfully placed JAS-1 into orbit with Amateur callsign 8J1JAS. Once it became a permanent part of the Amateur space effort, it was given the international designation of JO-12 for JAMSAT OSCAR 12. The JAMSAT organizers have unofficially dubbed the satellite Fuji, in honor of one of Japan's most famous landmarks.

Fuji, or FO-12, contains the more traditional type of linear transponders that allow normal voice and Morse code traffic as well as other modes to be relayed. Ground signals are transmitted on the 2 meter band and then relayed on 432 MHz.

For packet enthusiasts, the big news is that Fuji also carries a dedicated digital transponder. This is called mode JD. It has four discrete input channels and one downlink channel. The idea of having multiple input channels is based on the fact that the satellite has no control over ground activity. By having several channels available, the traffic can be spread out over a number of frequencies to help avoid interference and collisions. Since the satellite is in complete control of its own transmissions, only one channel is needed for transmitting.

## Connecting with Fuji/FO-12

So what does it take to actually use the digital transponder aboard Fuji? While the satellite has proven to be a good performer, it is not accessible with anything short of a well equipped station.

You must have both a 2 meter and 70 cm station. Relatively high gain antennas must be used and they must be capable of tracking the satellite as it zooms across the sky. Fuji resembles OSCAR 6 and 7 in that it is in low earth orbit and moves relatively quickly with respect to a point on Earth. You will also need a moderate amount of power, something on the order of 100 to 200 watts, definitely more than that available from a small hand-held radio!

Fuji provides an on-board flying mailbox or BBS system. Several configurations of the BBS software have been uploaded to the satellite from ground controllers, but typically 50 messages are allowed with a total storage area of approximately 192 kilobytes. A typical session with Fuji's mailbox is shown in *Figure 10-6*. (The "FO-12" in the figure is the common usage for JO-12. The various names for the one satellite are used interchangeably in the Amateur community.)

Additionally, Fuji can send telemetry via packet beacons. An example of a telemetry frame is shown in *Figure 10-7*.

While AX.25 protocol is used at 1200 bauds, the VHF standard, special modulation techniques are used that are incompatible with terrestrial packet modems. These choices were made to improve the signal to noise margin with weak satellite signals. The input channels on Fuji expect to see Manchester-coded FM signals. The output uses phase shift keying (PSK). In the United States, TAPR has made an external circuit board available that will generate the required Manchester coding for the uplink and properly receive the PSK on the downlink. This external modem can be connected to the TNC 1 and 2 or their compatibles. The cost of the kit is about that of an inexpensive TNC (\$100); however, this kit is *not* for a beginner.

**Figure 10-6.** This is an actual session with the mailbox aboard the Fuji satellite as monitored on Earth. The apparent misspellings are actually the way the Japanese sending station sent the text.

```

8J1JAS>JJ1ZUT <RR R F R2>
8J1JAS>JJ1ZUT <RR C P R2>
8J1JAS>JJ1ZUT <I C S4 R2>:
8J1JAS>JJ1ZUT **** F0-12 JAS-1 Mailbox System ****
Welcome to F0-12/JAS-1 Flying Mailbox system!

We, membe

8J1JAS>JJ1ZUT RR C P R2>
8J1JAS>JJ1ZUT <I C S5 R2>:
rs of JAMSAT JAS-1 project team are
glad to reliese the first version of the mailbox
software.

This version ( Ver. 1.0 ) has

8J1JAS>JJ1ZUT <I C S6 R2>:
some limitation
and is slightly different from the manual issued
software.

```

**Figure 10-7.** Fuji sends telemetry frames via packet radio. Computer programs are available for the home PC that will translate the telemetry frames into plain language text for evaluation.

```

8J1JAS>BEACON [06/21/87 04:55:41] <UI C>:
JAS-1 RA 87/06/21 05:02:58
266 558 716 721 778 879 891 864 003 386
647 002 585 623 624 618 620 622 687 001
699 695 708 701 804 676 925 502 000 000
010 111 100 000 100 000 001 011 111 000

8J1JAS>BEACON [06/21/87 04:55:42] <UI C>:
JAS-1 MO 87/06/21 05:03:00
Telemetry Information:
#00(1st):solar cell current = 1.91*(N-4) mA
#01(2nd):battery current = 3.81*(N-528)mA
#02(3rd):battery voltage = N/1000*21.0 v
#27:bat#depth of discharge = (N-500)/189 AH

```

## Why Must It Be Different?

If you are disappointed to learn that Fuji requires additional equipment and expertise, you are not alone. You must keep in mind, however, that Fuji's digital mode is on the leading edge of technology where everything tends to be difficult and expensive for a time. As access to space increases again and Amateur interest grows, the prices will tumble and the technology will improve.

## RUDAK

The latest satellite being prepared for launch is being designed by German Amateurs. The project is known as RUDAK (Regenerating Transponder for Digital Amateur Communications) and will be carried aboard a Phase III OSCAR satellite. Amateur satellites have been classified into several categories or phases. Phase III implies a satellite placed in a highly elliptical orbit. This type of orbit allows long periods of access for the highly populated areas of the world, but still allows some visibility from most points on Earth.

The RUDAK project will operate using an uplink data rate of 2400 bauds PSK with a downlink rate of 400 bauds PSK. This will make it incompatible with either Fuji or land-based packet modems.

Why do the designers do this? Both Fuji and RUDAK have been under development for a number of years. The engineers for each project have come to different conclusions about what encoding schemes, modulation techniques and baud rates will work most effectively. Remember that even what we consider the standard for packet activity is still quite young and subject to change. In the future, there may be a change to a common technique for both terrestrial and satellite communications.

For now, about all we can do is build equipment that will work with each system or wait for a standard to arise.

## A Closer Look at RUDAK

Even though there may be some adjustments necessary to participate in the RUDAK experiments, it does offer some distinct advantages over anything that has flown to date.

RUDAK will fly in an orbit similar to the Phase IIIB satellites such as OSCAR 10. While a Phase IIIB orbit is not geostationary like commercial communications satellites, it is a highly elliptical orbit that places the satellite within range of the northern hemisphere for periods of time often exceeding ten hours or more rather than a few minutes at a time. The good news is that when the satellite is near its peak altitude, little tracking is required. The bad news is that higher power and higher accuracy in antenna aiming is required to reach it in the high orbit.

Operation of RUDAK can be altered from the ground to accept new protocols or other programming, making it a very versatile satellite.

## SOME FINAL CONSIDERATIONS

In addition to the problems we've already discussed, anyone interested in doing packet work via satellite needs to be aware of some additional problems peculiar to space communications.



## Circular Polarization

While some attempt is made to stabilize an Amateur satellite once it is in orbit, the satellite is often allowed to maintain a slow spin. Depending on the type of antenna used on the spacecraft and the antenna used on the ground, the rotation can cause very deep fading or a flutter in the signal. The problem can be minimized by using a circularly polarized antenna. You've probably seen one of the more common types used for microwave work. It consists of a helically-wound element in front of a reflector.

While circular antennas do not have traditional horizontal or vertical polarization, they are sensitive to the *twist* of the signal. Think of the signal as traveling in a path something like the shape of a corkscrew. It can turn either clockwise or counter-clockwise. These are known as right-hand or left-hand polarization, respectively.

If your antenna is cross-polarized to the signal, the signal will almost completely disappear. When working with some satellites, you will find that the polarization may completely change from time to time due to the changing conditions of space, the atmosphere, and the attitude of the spacecraft itself. As a result, you need to have the ability to reverse the polarity sense of your antenna easily.

## Reducing Losses

Since many Amateur satellites operate at frequencies of 432 MHz or above, you must be particularly aware of signal losses between your indoor equipment and the outdoor antenna. You must use very high quality transmission line or coaxial cable.

If you have a TV satellite receiving dish, you know that a special *low noise amplifier* (LNA) is usually placed right at the antenna in order to get the best possible reception. The same is true for reception of Amateur satellite communications. You can place a receiving amplifier directly at the antenna, but if you plan to use the same antenna for transmitting, you must have a way to switch the amplifier out of the line so that it won't be harmed.

Remember that noise is the natural enemy of digital transmissions. Anything you can do to minimize the amount of noise you receive along with the desired signal will go a long way in helping you to properly receive incoming data.

## A Natural Satellite

If you would like to participate in digital space communications, but don't want to wait for an advanced communications satellite to make it easy for you, you can utilize a natural satellite that was around long before Marconi sent his message across the Atlantic.

For a number of years, Amateur Radio enthusiasts have pioneered the use of *moonbounce communications* to allow communications between remote points on Earth by bouncing a signal off the surface of the moon. Recent experiments using packet radio have proven that it can be done, though it takes extremely well equipped stations.

From time to time, hams are able to obtain permission to use one of the large radio telescopes for moonbounce experiments. With such an arrangement, packet communication using the moon as a passive reflector is possible.

## Esoteric Variations

Amateurs have also successfully used packet radio to bounce signals off the trails of meteors. The idea of *meteor scatter* communication is not a new one, but the use of packet for the purpose is. Meteor bursts tend to be rather short, so the bursty nature of packet transmissions is well suited to such work.

Alaskan Amateurs and others have also experimented with bouncing packet signals off of mountain peaks or using them to refract their signals back to Earth.

If you are adventuresome, you'll likely find an area of experimental work that will interest you, though having deep-pockets and a good location will certainly help!

## STARING INTO THE (NOT SO DISTANT) FUTURE

Imagine it's a sunny day. You pack the family up for a day at the beach. You don't particularly want to go swimming, so you take along your Model 200A, a futuristic laptop computer with a built-in packet radio modem.

While the family romps on the beach, you catch up on writing some notes to your friends overseas. First, there's a note to George in Stockholm. In the past, you used a conventional BBS to leave messages for one another. Today, you will use modern packet satellite technology to send your message. Then there's a note to Leon, a fellow computer hobbyist who was looking for pen pals through one of the magazines you read. Leon doesn't speak any English. No problem. Remember, this is the future.

You compose the notes off-line and then punch the send button on your computer. They are transmitted over a short distance to the nearest packet radio node where they begin their journey around the world.

A relay or two occurs before they are uplinked to a satellite orbiting high overhead. A bit later, the process is reversed. The messages are received at a communications port near each of your friends and then relayed directly to their computer. The message to Leon has been translated into a universal language using binary techniques that will appear on his computer screen in his native tongue.

A summer storm threatens your day at the beach, so you pack up the kids and head for home. Upon your arrival you find the "message waiting" lamp flashing on your home terminal. When you have the time to check, you find that your parents have left you several full-color pictures of themselves while they vacation in Hawaii.

All of this is possible because of a sophisticated packet radio network that links individual terminals through a network of nodes, switches and satellites around the world.

Far fetched you say? Don't blink! It will happen before you know it. You can begin to participate by getting involved with Amateur packet radio today. Jump in and get involved. It needn't be any more difficult than learning to use a telephone modem.

## T

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# Appendix

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## MANUFACTURERS

The following is a list of the manufacturers of packet hardware and software referred to in this book:

Advanced Electronic Applications  
P.O. Box C2160  
2006 196th SW  
Lynnwood, Washington 98036-0918

Brincomm Technology  
2404 Stockton Place  
Marietta, Georgia 30066

Electron Processing, Inc.  
P.O. Box 708  
Medford, N.Y. 11763

EXAR Corporation  
P.O. Box 49007  
2222 Qume Dr.  
San Jose, California 95161-9007

GLB Electronics  
151 Commerce Parkway  
Buffalo, New York 14224

Hamilton Area Packet Network  
Box 4466 Station D  
Hamilton, Ontario L8V 4S7

Jameco Electronics  
1355 Shoreway Road  
Belmont, California 94002

Kalt and Associates  
2440 East Tudor Road, Suite #138  
Anchorage, Alaska 99507  
(Suppliers of the Pak-Comm IBM terminal software)

Kantronics  
1202 East 23rd Street  
Lawrence, Kansas 66046

The Martin Company  
P.O. Box 982  
Marysville, Washington 98270  
(Terminal software for the TRS-80 computers)

Maxtec  
3721 Spring Valley Number 111  
Addison, Texas 75244  
(Connect alarm and lamp indicator)

MFJ Enterprises  
P.O. Box 494  
Mississippi State, Mississippi 39762

Pac-Comm Packet Radio Systems, Inc.  
3652 W. Cypress St.  
Tampa, Florida 33607-4916

Ronald Raikes, WA8DED  
9211 Pico Vista Road  
Downey, California 90240  
(TNC 1 Firmware)

Richcraft Engineering  
#1 Wahmeda Industrial Park  
Chautauqua, New York 14722  
(Sells TRS-80 software that makes the Model I or III a packet TNC. Also offers a three volume set of books on the software approach to packet radio.)

Texas Packet Radio Society  
P.O. Box 831566  
Richardson, TX 75083

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## MAJOR PACKET RADIO ORGANIZATIONS

These are the addresses for some of the major organizations active in packet radio. Since many of these are strictly volunteer organizations, be sure and enclose a self-addressed, stamped envelope when requesting information.

Amateur Radio Research and Development  
Corporation (AMRAD)  
PO Drawer 6148  
McLean, Virginia 22106-6148  
*Publishes the monthly AMRAD newsletter*

Amateur Radio Satellite Corporation  
(AMSAT)  
P.O. Box 27  
Washington, D.C. 20044  
*Good source for PACSAT information.*

Tucson Amateur Packet Radio Corporation  
(TAPR)  
PO Box 22888  
Tucson, Arizona 85734-2888  
*Publishes the Packet Status Register  
Quarterly*

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## AMATEUR RADIO MAGAZINES

Your best source for current packet information can often be found in amateur radio magazines. Here are a few that publish packet material:

CQ Magazine  
76 North Broadway  
Hicksville, New York 11801

Ham Radio Magazine  
Greenville, New Hampshire 03048

QST  
American Radio Relay League  
225 Main Street  
Newington, Connecticut 06111

World Radio  
2120 28th Street  
Sacramento, California 95818

73 Amateur Radio Magazine  
WGE Center  
Peterborough, New Hampshire 03458

HamNet  
c/o Scott Loftesness, W3VS  
16440 Rustling Oak Court  
Morgan Hill, California 95037

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## PACKET RADIO BOOKS AND ARTICLES

Over the years several books and many articles have been published about packet radio. Here are some of the best:

Max Adams, "Basic Amateur Radio Packet," *CQ* magazine, November 1985, pp. 13-20. An extensive introduction to packet radio. Very good!

ARRL Staff, Computer Network Conferences 1-5, Pioneer Papers on Packet Radio 1981-1985, (includes *Gateway Newsletter* through September 17, 1985.) Published 1985. Available from ARRL.

Terry Fox, *AX.25 Amateur Packet-Radio Link-Layer Protocol Version 2.0*, October 1984. All the details of link layer protocol. Available from ARRL.

Jim Grubbs, *Get \*\*\* CONNECTED to Packet Radio*, © 1986 QSKY Publishing.

Jim Grubbs, *The Digital Novice*, © 1987 QSKY Publishing.

Ian Hodgson, "An Introduction to Packet," *Ham Radio* magazine, June 1979, pp. 64-67. Packet radio in Canada.

Lyle Johnson, "Join the Packet Revolution," *73* magazine, September 1983, pp. 19-24. First of a "must read" series.

Lyle Johnson, "Join the Packet Revolution II," *73* magazine, October 1983, pp. 20-31. Second in the series.

Lyle Johnson, "Join the Packet Revolution III," *73* magazine, January 1984, pp. 36-44. Last in the series.

"Bulletin Board In Space," *Byte* magazine, May 1984, pp. 88-94. A description of the PACSAT project.

David McLanahan, "A Packet Radio Primer," *Ham Radio* magazine, December 1985, pp. 30-39. An introduction to packet radio.

Margaret Morrison et al, "Amateur Packet Radio Part I," *Ham Radio* magazine, July 1983, pp. 14-18. Packet basics.

Margaret Morrison et al, "Amateur Packet Radio Part II," *Ham Radio* magazine, August 1983, pp. 18-29. Part two of the series.

Harold Price, "What's All This Racket About Packet," *QST*, July 1985, pp. 14-17. A quick overview of packet radio.

Harold Price, "A Closer Look at Packet Radio," *QST*, August 1985, pp. 17-20. All about TNCs.

Robert Richardson, *Synchronous Packet Radio: The Software Approach*, Published 1982, Richcraft Engineering.

Robert Richardson, "Packet Radio: The Software Approach," *Ham Radio* magazine, September 1984, pp. 63-66. Using a TRS-80 for packet radio.

Paul Rinaldo, "Making of an Amateur Packet Network," *QST*, October 1981, pp. 28-30. Early packet.

George E. Friend et al, *Understanding Data Communications*, ©1984 Texas Instruments Incorporated. Available from Radio Shack as #62-1389. Overview of all data communications, including packet.



# Glossary

**ACK:** When information is received without any errors, the receiving station will ACKnowledge the transmission indicating that it has been received.

**AFSK:** Audio Frequency Shift Keying—the method of transmission used to send packets on VHF frequencies. Data is first converted into tone frequencies by a modem.

**AMTOR:** Amateur Teletype Over Radio—a sophisticated asynchronous form of communication that allows for a higher degree of error checking than RTTY, but not as great as packet.

**ARQ:** Automatic Repeat Request—a technique used to control errors. In amateur radio circles, AMTOR uses ARQ methods to insure almost error-free communications.

**ASCII:** American Standard Code for Information Interchange—one of the popular codes your computer uses.

**Asynchronous:** In data communications, asynchronous implies that each character is sent and received independently from other characters. Radio teletype is asynchronous since a character can begin at any time. See synchronous.

**AX.25 (Level Two):** Amateur radio link-level packet protocol adopted in October 1984 by the American Radio Relay League. See X.25.

**Baud:** A unit of speed used for data communications. Typically it measures the rate of signalling elements per second. It may be, but is not always, the same as bits per second.

**Baudot Code:** A five-level digital code on which radio-teletypewriter operation is based.

**BBS:** Bulletin Board System—refers to an electronic bulletin board service maintained by an individual or organization for the primary purpose of exchanging information and programs via digital transfer between computers.

**Beacon:** In packet terms, beacons are unconnected messages sent on a periodic basis automatically by a TNC.

**Bell 103, 202, 212:** Standards for data communication hardware originated by the Bell System specifying speed, tones, and so on. Bell 202 tones are the standard for VHF packet transmission. Bell 103 tones are used on HF.

**Bit Stuffing:** HDLC protocol does not allow for more than five one bits to be sent in a row, except during flag bytes. When this condition is detected, the transmitting TNC adds a zero after the fifth bit. The extra zero is removed on the receiving end. This is necessary so that data will not be confused with the begin and end packet flag character. It also provides a method for the receive station to extract the clock rate.

**BPS:** Bits Per Second—the number of actual data bits transmitted per second. With some modulation techniques, this is the same as baud rate. However, more sophisticated modulation schemes can encode multiple bits per baud so BPS and baud rate are not always the same.

**Collision:** In packet radio, a collision occurs when two stations' transmissions are detected by a receiving station at the same time.

**Connection:** The condition that exists when two stations are linked together in an error-checking fashion.

**CRC:** Cyclic Redundancy Check—a mathematical calculation performed by the transmitting station and included in outgoing packets. On the receive end, the CRC is recomputed and compared to that received. If they match, the packet is considered valid.

**CSMA:** Carrier Sense Multiple Access—a time sharing networking system that determines channel usage based on the presence or absence of a data carrier.

**DB-25:** A 25-pin hardware connector that is the defacto standard for interfacing DTE and DCE equipment using RS-232C signals.

**DCE:** Data Communication Equipment—in packet radio your TNC is generally the DCE. In telephone transmission, the modem is the DCE. It connects the terminal to the communication channel. See DTE.

**Digipeater:** Digital Repeater—a packet station used to relay packets from one station to another. All packet stations are capable of serving as digipeaters.

**DTE:** Data Terminal Equipment—in most packet stations, the home computer used as a terminal. Alternately, a stand-alone terminal, either electronic or mechanical.

**FAD:** Frame Assembler/Disassembler—the portion of a TNC that is responsible for forming data into frames of data for transmission including the header information and synchronization flags.

**FCS: Frame Check Sequence**—see CRC.

**FEC:** Forward Error Correction—a method to assure a great deal of accuracy in data transmission when no acknowledgement is possible.

**FidoNet:** A telephone-based bulletin board system utilizing store and forward techniques.

**Flag:** In packet radio, a special sequence that begins and ends each packet or frame. In AX.25 protocol 01111110 is the flag used.

**Frame:** A block of data that includes not only the information destined for the other station, but also the additional information necessary to get it there. A packet can consist of multiple frames of information.

**FSK:** Frequency Shift Keying—the method of transmission used on HF to send packets. See AFSK.

**Full Duplex:** In communications, this term implies that both stations can both send and receive data simultaneously.

**Gateway:** A node that translates information from one network into the form used in another network.

**Half Duplex:** Each station can both send and receive data over the communication path, but in only one direction at a time.

**HDLC:** Bit-oriented protocol developed by IBM. It is part of the foundation of AX.25.

**LAN:** Local Area Network—in packet radio LAN refers to a group of amateurs all operating on the same frequency in the same geographical area. Often a common digipeater is included in the LAN arrangement. See WAN.

**Master Station:** The controlling or transmitting station in a TOR communication. The two connected stations can switch roles by exchanging the proper command sequence. See Slave Station.

**Modem:** Short for MODulator/DEModulator. Generally the device used to transmit and receive data over a communication channel.

**NAK:** Negative Acknowledge—the opposite of ACK in some data transmission systems. If the information received is not considered to be valid, the receiving station will send a NAK back to the originator. In AX.25, NAKs are not used; they are implied rather than actually being sent.

**NNC:** Network Node Controller—similar to a TNC, but generally used at the trunking level of a network.

**Node:** In packet terms, a node is an individual station.

**NRZI:** Non-Return-to-Zero Inverted—a zero is represented by a shift from one state to another. A one is defined as no state change. RTTY operations on the other hand define a particular tone or level as one and another as zero. NRZI responds to changes, not the individual states.

**OSCAR:** Orbiting Satellite Carrying Amateur Radio—the family of communication satellites built by amateur radio operators.

**Packet:** A packet consists of one or more frames.

**PACSAT:** Packet Satellite—a low-orbit communications satellite employing store-and-forward packet radio techniques.

**PAM:** Packet Answering Machine—a simple, personal message system. See the text for more details.

**Parity:** A simple method of insuring the integrity of transmitted data.

**PBBS:** Packet Bulletin Board System—a PBBS is virtually identical to a telephone line BBS or a radio-teletype RBBS operation except that it operates on packet. The WORLI system is an example of a PBBS.

**PID:** Protocol IDentifier—part of the information in each frame of transmitted data. It identifies which version of network protocol is being used so that the station on the other end can adjust accordingly.

**Protocol:** A set of rules for communicating. This can include the speed used, the number of bits, the mark and space frequencies and much more. In packet radio, AX.25 is the current form of protocol being used. It defines many different aspects of the mode.

**PSK:** Phase-shift keying.

**RTTY:** Radio TeleTYpewriter operation—sometimes called RATT (Radio Amateur Tele-Typewriter).

**RUDAK:** Regenerating Transponder for Digital Amateur Communications—an Amateur Radio satellite transponder that uses 1269 MHz, 2400 baud, PSK uplink and 400 baud, PSK 435 MHz downlink.



## G

**Slave Station:** The receiving or controlled station in a TOR communication. See Master Station.

**SSID:** Secondary Station ID—in packet radio each station can designate up to sixteen separate operations. K9EI-1 for example might be a digipeater, while K9EI-2 could be a PBBS operation.

**Start and Stop Bits:** The first and last bits, respectively, used in asynchronous communications to signal the beginning and end, respectively, of each transmitted character.

**Store and Forward:** A system where messages are received, held until an appropriate time and then retransmitted to another station.

**Synchronous:** In data communications, a bit stream having a constant time interval between successive bits. The sending and receiving stations must be synchronized to a common clock signal. Packet radio is a synchronous form of data transmission.

**Terminal Unit:** The device used to convert audio tones back into current or voltage levels for interpretation by computers or mechanical DTE. Modern language has replaced this term with Radio Modem or Computer Patch.

**Throughput:** While bit transmission on a packet channel takes place at a relatively high speed (1200 baud on VHF, 300 baud on HF) the actual effective speed of transmission can be much less. The actual effective transmission speed is referred to as throughput. Interference, multiple-repeats and other factors reduce throughput.

**TNC:** Terminal Node Controller—the device used to interface a radio channel to a terminal device.

**Vancouver Protocol:** A popular form of packet radio protocol used in areas of the world largely outside the United States.

**WAN:** Wide Area Network—if a super digipeater is used to cover a wide geographical area, it can be thought of as the nucleus of a wide area network. Generally such systems work best only in areas where packet activity is low and the terrain allows stations over a very wide area to access the central digipeater. Also defined in the OSI network model as a collection of LANs.

**X.25:** A packet switching protocol designed by international agreement for packet switched networks. Many of the elements of X.25 inspired the Amateur Radio implementation of packet techniques, AX.25.

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Are you a computer hobbyist looking for new ways to communicate with your fellow hackers? Are you a ham wanting to expand your Amateur Radio network? Communications using digital techniques—and specifically *packet data communications*—is your next exciting step. And a new dimension can be added—substituting an Amateur Radio link for the common telephone modem.

## Digital Communications with Amateur Radio

Explains the Amateur Radio and digital techniques required and provides

### **The Computer Hobbyist:**

- A review of telephone line digital communications.
- An understanding of Amateur Radio links and interfaces.
- An understanding of packet radio techniques and protocols.
- How to use computers for a packet radio interface.

### **The Amateur Radio Operator:**

- An understanding of digital techniques for communication.
- An understanding of how to interface digital equipment and ham gear.
- An understanding of packet radio techniques and protocols.
- An understanding of how to get connected and operating.

The star of *Digital Communications with Amateur Radio* is *packet radio* and the equipment required. What the equipment is, how to interface it, how to use and operate it to get connected via the Amateur Radio link. And then going further—with networking and satellites.

### **About the Author**

Jim Grubbs was first licensed as Novice Amateur Radio operator KN9EIV more than 27 years ago at age 11. He now holds an Extra Class license with special call sign K9EI. Jim also holds the highest FCC commercial radio telephone license, the First Class (now General) Radiotelephone Certificate with radar endorsement. Additionally, he holds a Second-Class Radiotelegraph license and is certified as capable of receiving Morse code (by ear) at over 40 words per minute. Jim was the sixteenth person to successfully establish contact with all 50 of the United States using an Amateur Radio satellite.

Jim has authored over 300 columns and articles for popular Amateur and computer magazines including: *Ham Radio*, *73*, *Popular Communications*, *RUN*, *Transactor*, *Commander*, *Link-Up*, *Commodore User* (London), *Radio Sweden International*, *Tele*, *Amiga World* and many others. He has published five books of which *Get \*\*\* CONNECTED to Packet Radio* and *The Digital Novice* (both by QSKY Publishing), and *Growing Up In The Military* (by inDependent Publishing) are the most well known. He also publishes *iD* a magazine for both current and former military dependents.

Jim has taught FCC licensing in community colleges, and is popular at many hamfests and computer camps as a guest lecturer and teacher.

While doing commercial broadcasting, Billboard Magazine awarded Jim the title "one of the best on-the-air personalities in radio." He is an alumnus of the Armed Forces Radio and Television Service in Japan, and has lived as an Air Force dependent in Japan, Okinawa and Hawaii.

Jim was among the first thousand or so packet operators on the air using an early TAPR designed terminal node controller. He maintains a keen interest in satellite communications and the space program.

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